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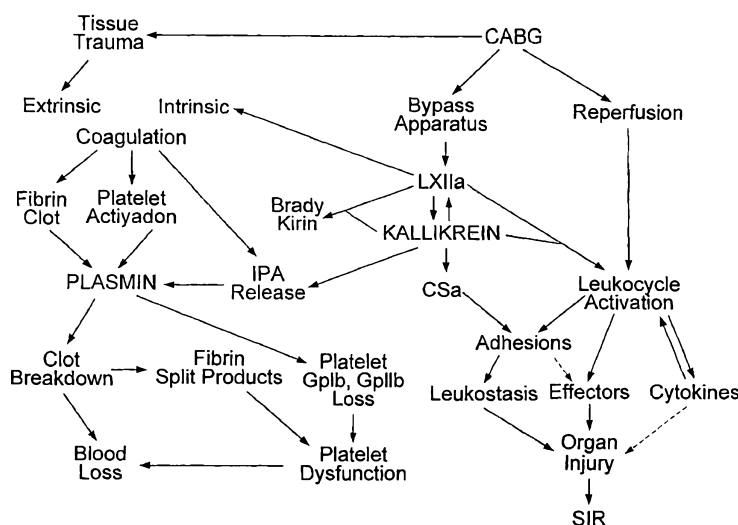
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(54) Title: KALLIKREIN INHIBITORS AND USES THEREOF



(57) Abstract: Methods, kits and compositions are described that include a non-naturally occurring kallikrein inhibitor and an anti-thrombolytic agent, e.g., an anti-fibrinolytic agent, for preventing or reducing blood loss and/or ischemia, e.g., ischemia associated with perioperative blood loss and cerebral ischemia, the onset of systemic inflammatory response, and/or reperfusion injury, e.g., reperfusion injury associated with cerebral ischemia or a focal brain ischemia, e.g., in patients subjected to invasive surgical procedures, especially procedures requiring cardiopulmonary bypass. Methods are described for preventing or reducing ischemia, e.g., cerebral ischemia, and/or reperfusion injury, e.g., reperfusion injury associated with cerebral ischemia, in a patient by administering a kallikrein inhibitor.

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Kallikrein Inhibitors and Uses Thereof

TECHNICAL FIELD

This invention is generally in the field of invasive surgical procedures associated with contact activation of complement components and the
5 coagulation/fibrinolysis systems. More specifically, the invention provides methods, kits and compositions utilizing a non-naturally occurring kallikrein inhibitor to reduce or prevent blood loss, e.g., perioperative blood loss, and/or injury associated with various ischemias, e.g., in patients subjected to invasive surgical procedures. For example, the invention provides methods, kits and compositions for reducing blood
10 loss associated with procedures requiring cardiopulmonary bypass. Preferably, the invention provides methods, kits and compositions utilizing a combination of a non-naturally occurring kallikrein inhibitor and an anti-thrombolytic agent, e.g., an anti-fibrinolytic agent.

BACKGROUND

15 Owing to the many advances in medicine a number of highly invasive surgical procedures are carried out each day that result in blood loss, or place patients at a high risk for blood loss. Such patients must be carefully monitored to restore and maintain normal blood supply and hemostasis, and they may need blood transfusions. Surgical procedures that involve blood loss include those involving extra-corporeal circulation
20 methods such as cardiopulmonary bypass (CPB). In such methods, a patient's heart is stopped and the circulation, oxygenation, and maintenance of blood volume are carried out artificially using an extra-corporeal circuit and a synthetic membrane oxygenator. These techniques are commonly used during cardiac surgery. Additionally, it is apparent that surgery involving extensive trauma to bone, such as
25 the sternal split necessary in coronary artery bypass grafting (CABG) or hip replacement procedures, is also associated with activation of the contact activation system (CAS), which can result in a variety of disruptions in the blood and vasculature.

Atherosclerotic coronary artery disease (CAD) causes a narrowing of the
30 lumen of one or several of the coronary arteries; this limits the flow of blood to the myocardium (i.e., the heart muscle) and can cause angina, heart failure, and

myocardial infarcts. In the end stage of coronary artery atherosclerosis, the coronary circulation can be almost completely occluded, causing life threatening angina or heart failure, with a very high mortality. CABG procedures may be required to bridge the occluded blood vessel and restore blood to the heart; these are potentially life saving. CABG procedures are among the most invasive of surgeries in which one or more healthy veins or arteries are implanted to provide a "bypass" around the occluded area of the diseased vessel.

The number of CABG procedures performed in the United States in 1998 was approximately 500,000. CABG procedures carry with them a small but important perioperative risk, but they are very successful in providing patients with immediate relief from the mortality and morbidity of atherosclerotic cardiovascular disease. Despite these very encouraging results, repeat CABG procedures are not uncommon, as indicated by a clear increase in the number of patients who eventually undergo second and even third procedures; the perioperative mortality and morbidity seen in primary CABG procedures is increased in these re-do procedures.

There have been improvements in minimally invasive surgical techniques for uncomplicated CAD. However, nearly all CABG procedures performed for valvular and/or congenital heart disease, heart transplantation, and major aortic procedures, are still carried out on patients supported by CPB. In CPB, large cannulae are inserted into the great vessels of a patient to permit mechanical pumping and oxygenation of the blood using a membrane oxygenator. The blood is returned to the patient without flowing through the lungs, which are hypoperfused during this procedure. The heart is stopped using a cardioplegic solution, the patient cooled to help prevent brain damage, and the peripheral circulating volume increased by an extracorporeal circuit, i.e., the CPB circuit, which requires "priming" with donor blood and saline mixtures are used to fill the extracorporeal circuit. CPB has been extensively used in a variety of procedures performed for nearly half a century with successful outcomes. The interaction between artificial surfaces, blood cells, blood proteins, damaged vascular endothelium, and extravascular tissues, such as bone, disturbs hemostasis and frequently activates the CAS, which, as noted above, can result in a variety of disruptions in the blood and vasculature. Such disruption leads to excess perioperative bleeding, which then requires immediate blood transfusion. A consequence of circulating whole blood through an extracorporeal circuit in CPB may also include the systemic inflammatory response (SIR), which is initiated by contact

activation of the coagulation and complement systems. Indeed, much of the morbidity and mortality associated with seemingly mechanically successful CPB surgical procedures is the result of the effects of activating coagulation, fibrinolysis, or complement systems. Such activation may damage the pulmonary system, leading to adult respiratory distress syndrome (ARDS), impairment of kidney and splanchnic circulation, and induction of a general coagulopathy leading to blood loss and the need for transfusions. In addition to the dangers of perioperative blood loss, additional pathologies associated with SIR include neurocognitive deficits, stroke, renal failure, acute myocardial infarct, and cardiac tissue damage.

Blood transfusions also present a significant risk of infection and elevate the cost of CABG or other similar procedures that require CPB. In the absence of any pharmacological intervention, three to seven units of blood must typically be expended on a patient, even with excellent surgical techniques. Accordingly, there is considerable incentive for the development of new and improved treatments to reduce or prevent perioperative bleeding and SIR in patients subjected to CPB and CABG procedures.

SUMMARY

The disclosure is based, at least in part, on the discovery that a combination of a non-naturally occurring kallikrein inhibitor, e.g., a Kunitz domain kallikrein inhibitor polypeptide, and an anti-thrombolytic agent, e.g., an anti-fibrinolytic agent, can be administered to a subject to eliminate or reduce blood loss, e.g., perioperative blood loss, as well as injury associated with ischemia (including ischemia associated with perioperative blood loss and cerebral ischemia), the onset of systemic inflammatory response, and/or reperfusion injury, e.g., reperfusion injury associated with cerebral ischemia or a focal brain ischemia. In one embodiment, the treatment can reduce or eliminate blood loss by one or more of: reducing or eliminating bleeding, capillary leakage and alterations in body fluid balance. The treatment can be in patients subjected to invasive surgical procedures such as, e.g., cardiothoracic surgery (e.g., cardiopulmonary bypass), orthopedic surgery (e.g., hip or knee replacement or fracture), hepatectomy, nephrectomy. The invasive surgical procedure can involve the use of extracorporeal circulation or dialysis. Preferably, the treatment is more effective because of the combined administration. For example, the anti-thrombolytic agent is more effective, e.g., an equivalent effect is seen with less of the

anti-thrombolytic agent, the anti-thrombolytic treatment reduces symptoms to a greater extent than would be seen if the anti-thrombolytic treatment were administered in the absence of the non-naturally occurring kallikrein inhibitor, and/or an unwanted side effect associated with the anti-thrombolytic agent is seen less than
5 would be seen if the anti-thrombolytic agent was administered in the absence of the non-naturally occurring kallikrein inhibitor, or the analogous situation is seen with the non-naturally occurring kallikrein inhibitor.

Accordingly, the disclosure features methods, compositions and kits that include a non-naturally occurring kallikrein inhibitor, e.g., a plasma kallikrein
10 inhibitor, and an anti-thrombolytic agent, to eliminate or reduce blood loss and/or injury associated with ischemias. Preferably, the anti-thrombolytic agent is an anti-fibrinolytic agent, e.g., an anti-fibrinolytic agent described herein. Anti-fibrinolytic agents can be one or more of: tranexamic acid (CyklokapronTM), epsilon amino caproic acid (AmicarTM), aprotinin (TrasyolTM), Desmopressin (DDAVP), and
15 pirfenidone.

In one aspect, the disclosure features a method for preventing or reducing blood loss in a patient that includes administering to the patient a non-naturally occurring inhibitor of kallikrein, e.g., a plasma kallikrein, in combination with an anti-thrombolytic agent, e.g., an anti-fibrinolytic agent. Typically, the patient is a human
20 patient. The combination of the inhibitor of kallikrein and the anti-thrombolytic agent can be administered in an amount effective to prevent or reduce blood loss (e.g., prevent or reduce one or more of: bleeding, capillary leakage and alterations in body fluid balance). In a particular embodiment, the blood loss is perioperative blood loss is due to a surgical procedure performed on the patient. The surgical procedure can
25 be, e.g., a cardiothoracic surgery, (e.g., cardiopulmonary bypass or coronary artery bypass grafting); orthopedic surgery (e.g., hip or knee replacement or bone fracture); hepatectomy; nephrectomy; procedures that utilize extracorporeal circulation or dialysis; and any other procedure which can result in perioperative blood loss. The inhibitor and/or the anti-thrombolytic agent can be administered before, during, or
30 after the procedure. In one embodiment, the method reduces the amount or need for a transfusion before, during or after the procedure.

In another aspect, the disclosure features a kit for preventing or reducing blood loss, e.g., perioperative blood loss due to a surgical procedure performed on the patient. The kit can include a non-naturally occurring inhibitor of kallikrein, e.g.,

plasma kallikrein, and instructions for administering the inhibitor in combination with an anti-thrombolytic agent, e.g., an anti-fibrinolytic agent. In one embodiment, the instructions provide a dosing regimen, dosing schedule, and/or route of administration of the inhibitor that differs from the dosing regimen, dosing schedule and/or route of administration for the inhibitor in the absence of the anti-thrombolytic agent. In one
5 embodiment, the kit further includes an anti-thrombolytic agent, e.g., an anti-fibrinolytic agent.

In another aspect, the disclosure features a method for preventing or reducing
10 injury associated with ischemia in a patient that includes administering to the patient a non-naturally occurring inhibitor of kallikrein, e.g., a plasma kallikrein, in combination with an anti-thrombolytic agent, e.g., an anti-fibrinolytic agent. Typically, the patient is a human patient. The combination of the inhibitor of kallikrein and the anti-thrombolytic agent can be administered in an amount effective
15 to prevent or reduce an injury associated with ischemia in the patient. In a particular embodiment, the ischemia is at least partially due to blood loss, e.g., perioperative blood loss due to a surgical procedure performed on the patient. The surgical procedure can be, e.g., a cardiothoracic surgery, (e.g., cardiopulmonary bypass or coronary artery bypass grafting); orthopedic surgery (e.g., hip or knee replacement or
20 bone fracture); hepatectomy; nephrectomy; procedures that utilize extracorporeal circulation or dialysis; and any other procedure which can result in perioperative blood loss. The inhibitor and/or the anti-thrombolytic agent can be administered before, during, or after the procedure.

In another aspect, the disclosure features a kit for preventing or reducing
25 injury associated with ischemia in a patient, e.g., ischemia at least partially due to blood loss, e.g., perioperative blood loss due to a surgical procedure performed on the patient. The kit can include a non-naturally occurring inhibitor of kallikrein, e.g., plasma kallikrein, and instructions for administering the inhibitor in combination with an anti-thrombolytic agent, e.g., an anti-fibrinolytic agent. In one embodiment, the
30 instructions provide a dosing regimen, dosing schedule, and/or route of administration of the inhibitor that differs from the dosing regimen, dosing schedule and/or route of administration for the inhibitor in the absence of the anti-thrombolytic agent. In one embodiment, the kit further includes an anti-thrombolytic agent, e.g., an anti-fibrinolytic agent.

In another aspect, the disclosure features a method for preventing or reducing a systemic inflammatory response, e.g., a response associated with a surgical procedure in a patient or its onset. The method includes: administering to the patient a non-naturally occurring inhibitor of kallikrein, e.g., plasma kallikrein, in
5 combination with an anti-thrombolytic agent, e.g., an anti-fibrinolytic agent. Typically, the patient is a human patient. The inhibitor and/or the anti-thrombolytic agent can be administered before, during, or after surgery. In one embodiment, the surgical procedure is a cardiothoracic surgery, (e.g., cardiopulmonary bypass or coronary artery bypass grafting); orthopedic surgery (e.g., hip or knee replacement or
10 bone fracture); hepatectomy; nephrectomy; a procedure that utilize extracorporeal circulation or dialysis; and any other procedure which can result in perioperative blood loss.

In another aspect, the disclosure features a kit for preventing or reducing systemic inflammatory response, e.g., a response associated with a surgical procedure
15 in a patient or its onset. The kit can include a non-naturally occurring inhibitor of kallikrein, e.g., plasma kallikrein, and instructions for administering the inhibitor in combination with an anti-thrombolytic agent, e.g., an anti-fibrinolytic agent. In one embodiment, the instructions provide a dosing regimen, dosing schedule, and/or route of administration of the inhibitor that differs from the dosing regimen, dosing
20 schedule and/or route of administration for the inhibitor in the absence of the anti-thrombolytic agent. In one embodiment, the kit further includes an anti-thrombolytic agent, e.g., an anti-fibrinolytic agent.

In another aspect, the disclosure features a method for treating a brain or central nervous system (CNS) injury. The method can be used to prevent or reduce
25 adverse effects of cerebral ischemia, e.g., stroke, and/or reperfusion injury, e.g., reperfusion injury associated with cerebral ischemia, in a patient including administering to the patient a non-naturally occurring inhibitor of kallikrein. In some embodiments, the method further includes administering an anti-thrombolytic agent, e.g., an anti-fibrinolytic agent. In one embodiment, the cerebral ischemia is stroke,
30 e.g., embolism-, thrombus- or hemorrhage-associated stroke. The method can include administering the inhibitor and/or the anti-thrombolytic agent, before, during, or after the ischemia, e.g., at the time of reperfusion or at a time between 1-12 hours after an ischemic event, e.g., between 1-5 hours after such an event.

In another aspect, the disclosure features a kit for treating a brain or central nervous system (CNS) injury, e.g., to prevent or reduce adverse effects of cerebral ischemia, e.g., stroke, and/or reperfusion injury, e.g., reperfusion injury associated with cerebral ischemia. In one embodiment, the cerebral ischemia is stroke, e.g., embolism-, thrombus- or hemorrhage-associated stroke. The kit can include a non-naturally occurring inhibitor of kallikrein, e.g., plasma kallikrein, and instructions for administering the inhibitor in combination with an anti-thrombolytic agent, e.g., an anti-fibrinolytic agent. In one embodiment, the instructions provide a dosing regimen, dosing schedule, and/or route of administration of the inhibitor that differs from the dosing regimen, dosing schedule and/or route of administration for the inhibitor in the absence of the anti-thrombolytic agent. In one embodiment, the kit further includes an anti-thrombolytic agent, e.g., an anti-fibrinolytic agent.

The disclosure also features a composition that includes a non-naturally occurring inhibitor of kallikrein, e.g., a plasma kallikrein, and an anti-thrombolytic agent, e.g., an anti-fibrinolytic agent. The composition can further include a pharmaceutically acceptable carrier, stabilizer and/or excipient.

The non-naturally occurring kallikrein inhibitor used in any disclosed method, kit or composition can have one or more of the characteristics described below.

The kallikrein inhibitor can have a K_i for kallikrein, e.g., plasma kallikrein, of less than 50 nM, 40 nM, 30 nM, 20 nM, 5 nM, 1 nM, 500 pM, 100 pM, 50 pM, e.g., about 44 pM. The kallikrein inhibitor can preferentially inhibit plasma kallikrein at least 100, 200, 500, or 1000 more than another kallikrein, e.g., human urine kallikrein, or another protease, e.g., plasmin or thrombin.

In one embodiment, the kallikrein inhibitor is an agent that can cross the blood-brain barrier.

In one embodiment, the kallikrein inhibitor includes a polypeptide that includes a Kunitz domain such as the amino acid sequence: Xaa1 Xaa2 Xaa3 Xaa4 Cys Xaa6 Xaa7 Xaa8 Xaa9 Xaa10 Xaa11 Gly Xaa13 Cys Xaa15 Xaa16 Xaa17 Xaa18 Xaa19 Xaa20 Xaa21 Xaa22 Xaa23 Xaa24 Xaa25 Xaa26 Xaa27 Xaa28 Xaa29 Cys Xaa31 Xaa32 Phe Xaa34 Xaa35 Gly Gly Cys Xaa39 Xaa40 Xaa41 Xaa42 Xaa43 Xaa44 Xaa45 Xaa46 Xaa47 Xaa48 Xaa49 Xaa50 Cys Xaa52 Xaa53 Xaa54 Cys Xaa56 Xaa57 Xaa58 (SEQ ID NO:1).

The framework of the Kunitz domain can be human or can differ from a human Kunitz domain framework by fewer than six, five, four, three, or two amino acids. For example, the framework of the Kunitz domain can be the framework of one of the Kunitz domains of human lipoprotein-associated coagulation inhibitor (LACI) protein, e.g., the first second or third Kunitz domain. LACI is also known as "Tissue Factor Pathway Inhibitor" or "TFPI". Typically, the polypeptide differs from BPTI and/or one or more of the LACI Kunitz domains by at least one, two, three, or four amino acids, e.g., at least one, two or three amino acids in the binding loops and/or at least two, three, four, or six amino acids in the framework region. For example, the polypeptide can include a non-naturally occurring Kunitz domain that is derived from a naturally occurring Kunitz domain, e.g., a human Kunitz domain. In one embodiment, an inhibitor that includes a Kunitz domain binds to plasma kallikrein with an affinity that is at least 10, 100, or 500 fold better than BPTI and/or LACI.

In one embodiment, the polypeptide that inhibits kallikrein is not immunogenic on second use.

In one embodiment, the polypeptide that inhibits kallikrein can have one or more of the following features: Xaa1, Xaa2, Xaa3, Xaa4, Xaa56, Xaa57 or Xaa58 are each individually an amino acid or absent; Xaa10 is an amino acid selected from the group consisting of: Asp and Glu; Xaa11 is an amino acid selected from the group consisting of: Asp, Gly, Ser, Val, Asn, Ile, Ala and Thr; Xaa13 is an amino acid selected from the group consisting of: Arg, His, Pro, Asn, Ser, Thr, Ala, Gly, Lys and Gln; Xaa15 is an amino acid selected from the group consisting of: Arg, Lys, Ala, Ser, Gly, Met, Asn and Gln; Xaa16 is an amino acid selected from the group consisting of: Ala, Gly, Ser, Asp and Asn; Xaa17 is an amino acid selected from the group consisting of: Ala, Asn, Ser, Ile, Gly, Val, Gln and Thr; Xaa18 is an amino acid selected from the group consisting of: His, Leu, Gln and Ala; Xaa19 is an amino acid selected from the group consisting of: Pro, Gln, Leu, Asn and Ile; Xaa21 is an amino acid selected from the group consisting of: Trp, Phe, Tyr, His and Ile; Xaa22 is an amino acid selected from the group consisting of: Tyr and Phe; Xaa23 is an amino acid selected from the group consisting of: Tyr and Phe; Xaa31 is an amino acid selected from the group consisting of: Glu, Asp, Gln, Asn, Ser, Ala, Val, Leu, Ile and Thr; Xaa32 is an amino acid selected from the group consisting of: Glu, Gln, Asp, Asn, Pro, Thr, Leu, Ser, Ala, Gly and Val; Xaa34 is an amino acid selected from the

group consisting of: Thr, Ile, Ser, Val, Ala, Asn, Gly and Leu; Xaa35 is an amino acid selected from the group consisting of: Tyr, Trp and Phe; Xaa39 is an amino acid selected from the group consisting of: Glu, Gly, Ala, Ser and Asp; Xaa40 is an amino acid selected from the group consisting of: Gly and Ala; Xaa43 is an amino acid
5 selected from the group consisting of: Asn and Gly; Xaa45 is an amino acid selected from the group consisting of: Phe and Tyr; and wherein the polypeptide inhibits kallikrein.

In a particular embodiment, individual amino acid positions of a kallikrein inhibitor that includes the amino acid sequence of SEQ ID NO:1 has one or more of
10 the following: Xaa10 is Asp, Xaa11 is Asp, Xaa13 is Pro, Xaa15 is Arg, Xaa16 is Ala, Xaa17 is Ala, Xaa18 is His, Xaa19 is Pro, Xaa21 is Trp, Xaa31 is Glu, Xaa32 is Glu, Xaa34 is Ile, Xaa35 is Tyr, Xaa39 is Glu.

The polypeptide that inhibits kallikrein can include (or consist of) the following amino acid sequence: Met His Ser Phe Cys Ala Phe Lys Ala Asp Asp Gly
15 Pro Cys Arg Ala Ala His Pro Arg Trp Phe Phe Asn Ile Phe Thr Arg Gln Cys Glu Glu Phe Ile Tyr Gly Gly Cys Glu Gly Asn Gln Asn Arg Phe Glu Ser Leu Glu Glu Cys Lys Lys Met Cys Thr Arg Asp (amino acids 3-60 of SEQ ID NO:2), or a fragment thereof, e.g., a fragment that binds and inhibits kallikrein. For example, the polypeptide can have fewer than 80, 70, 65, 60, 58, 55 or 52 amino acids.

20 The polypeptide that inhibits kallikrein can include (or consist of) a polypeptide described in U.S. Patent No: 5,786,328, the contents of which are incorporated by reference.

Methods, kits and compositions described herein can include an inhibitor that comprises a non-naturally occurring, Kunitz domain polypeptide having any of the
25 amino acid sequences described herein and an additional flanking sequence of one to six amino acids at the amino and/or carboxy terminal end domains. Such additional amino acids may be artifacts of expressing a particular non-naturally occurring kallikrein inhibitor polypeptide or Kunitz domain polypeptide in any of a variety of recombinant expression vector systems, such as used in yeast, bacteria, mammalian
30 cell lines, insect cells, and the like. Preferably, such additional amino acids at the amino and/or carboxy termini of a non-naturally occurring Kunitz domain described herein do not diminish the affinity for kallikrein or kallikrein inhibition activity of the domain or a polypeptide comprising the domain.

The inhibitor polypeptide can include a non-naturally occurring Kunitz domain polypeptide having an amino acid sequence of SEQ ID NO:1 and an amino terminal flanking sequence as the result of producing the polypeptide as a recombinant protein in yeast. An example of a particularly preferred yeast

5 recombinant expression system comprises fusing a nucleotide coding sequence for a non-naturally occurring Kunitz domain of SEQ ID NO:1 to a nucleotide sequence encoding the mat α Prepro peptide leader sequence of *Saccharomyces cerevisiae* and expressing the recombinant coding sequence in the yeast *Pichia pastoris*. The resulting expressed fusion protein comprises an amino acid sequence of SEQ ID NO:1

10 and an amino terminal flanking dipeptide, Glu-Ala. A particularly preferred species of an inhibitor polypeptide of the invention produced in a yeast expression system has the amino acid sequence of SEQ ID NO:2:

Glu Ala Met His Ser Phe Cys Ala Phe Lys Ala Asp Asp Gly Pro Cys Arg Ala
 Ala His Pro Arg Trp Phe Phe Asn Ile Phe Thr Arg Gln Cys Glu Glu Phe Ile Tyr Gly
 15 Gly Cys Glu Gly Asn Gln Asn Arg Phe Glu Ser Leu Glu Glu Cys Lys Lys Met Cys
 Thr Arg Asp (SEQ ID NO:2).

In one embodiment, the polypeptide that inhibits kallikrein is modified, e.g., to include one or more moieties, e.g., one or more moieties that extend half life of the polypeptide, e.g., a polymer moiety or a plurality of polymer moieties, e.g., as

20 described in U.S.S.N. 10/931,153, filed August 30, 2004, bearing attorney docket number 10280-119001. For example, the polypeptide can include a plurality of polyethylene glycol moieties, e.g., one on an N-terminal amine and one attached to each lysine of the polypeptide. The polyethylene glycol moieties can be less than 10, 8, 7, or 6 kDa in average molecular weight. In other embodiments, the moiety can be,

25 e.g., serum albumin, e.g., human serum albumin. Other exemplary modifications include a label, e.g., a radioactive or MRI-detectable label. In some embodiments, the polypeptide is part of a mixture that includes modified and unmodified polypeptides that inhibit kallikrein. For example, the mixture can include one or more modified polypeptides that inhibit kallikrein and that include a polymer moiety such as a

30 polyethylene glycol moiety and one or more unmodified polypeptides that inhibit kallikrein and do not include a polymer moiety. In one embodiment, approximately 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% or all of the polypeptides that inhibit kallikrein in the mixture are modified.

The kallikrein inhibitor polypeptides useful in the methods, compositions and kits may be any of the non-naturally occurring Kunitz domain polypeptides described herein or larger polypeptides comprising any such Kunitz domains, provided the kallikrein inhibitor polypeptides bind and inhibit kallikrein as determined in standard
5 assays.

The anti-thrombolytic agent used in any disclosed method, kit or composition can be an anti-fibrinolytic agent. Examples of anti-fibrinolytic agents include: tranexamic acid (CyklokapronTM), epsilon amino caproic acid (AmicarTM), aprotinin
10 (TrasyolTM), Desmopressin (DDAVP), pirfenidone, and combinations thereof. In one embodiment, the anti-thrombolytic agent is an anti-fibrinolytic agent selected from epsilon amino caproic acid (AmicarTM), aprotinin (TrasyolTM), and combinations thereof.

15 The methods described herein can include administering an effective amount of the combination treatment. Such an amount can be an amount sufficient to produce an improvement detectable to one skilled in the art, to ameliorate at least one symptom, or to modulate (e.g., improve) at least one physiological parameter, e.g., to a statistically significant degree.

20 Preferred compositions, e.g., used in any method or kit described herein, may further comprise one or more pharmaceutically acceptable buffers, carriers, and excipients, which may provide a desirable feature to the composition including, but not limited to, enhanced administration of the composition to a patient, enhanced
25 circulating half-life of the inhibitor and/or anti-thrombolytic agent, enhanced compatibility of the composition with patient blood chemistry, enhanced storage of the composition, and/or enhanced efficacy of the composition upon administration to a patient.

30 Preferred methods described herein are useful for preventing or reducing perioperative blood loss and/or SIR in a patient subjected to a surgical procedure such as a surgical procedure that requires extra-corporeal circulation (e.g., cardiopulmonary bypass (CPB)) or dialysis. Particularly preferred are methods of the invention for preventing or reducing perioperative blood loss and/or SIR in a patient

subjected to a surgical procedure comprising administering to the patient of a kallikrein inhibitor polypeptide described herein, in combination with an anti-thrombolytic agent, e.g., an anti-fibrinolytic agent, wherein the surgical procedure requires cardiopulmonary bypass (CPB) and the surgical procedure is a coronary artery bypass graft (CABG) procedure.

Methods described herein may be carried out on a patient before, during, and/or after the surgical procedure. Particularly preferred is the use of the methods before and during a surgical procedure, especially in the case of CABG procedures to prevent perioperative blood loss by activation of the contact activation system and the onset of SIR.

In another embodiment, the invention provides nucleic acid molecules comprising nucleotide sequences coding for a non-naturally occurring Kunitz domain or kallikrein inhibitor polypeptide described herein. Such nucleic acid molecules may be any of a variety of nucleic acid molecules including, but not limited to, a recombinant phage genome, a recombinant mammalian viral vector, a recombinant insect viral vector, a yeast mini chromosome, and a plasmid. Preferred plasmid molecules of the invention include but are not limited to yeast expression plasmids, bacterial expression plasmids, and mammalian expression plasmids. Nucleic acid molecules useful in the invention may comprise a specific nucleotide sequence described herein or a degenerate form thereof.

Particularly preferred nucleic acid molecules of the invention include a nucleic acid molecule comprising a nucleotide sequence as shown in Figure 2 encoding a fusion protein comprising a mat α Prepro signal peptide fused to a heretofore undisclosed kallikrein inhibitor polypeptide, nucleic acid molecules comprising the nucleotide sequence encoding the kallikrein inhibitor polypeptide having an amino acid of SEQ ID NO:2, and nucleic acid molecules comprising a nucleotide sequence encoding a kallikrein inhibitor polypeptide having an amino acid sequence of amino acids 3-60 of SEQ ID NO:2.

The details of one or more embodiments of the invention are set forth in the accompanying drawings and the description below. Other features, objects, and advantages of the invention will be apparent from the description and drawings, and from the claims.

BRIEF DESCRIPTION OF THE FIGURES

Figure 1 is a simplified diagram of major multiple pathways and related events involved in the contact activation system and systemic inflammatory response (SIR) that may arise in a patient subjected to soft and bone tissue trauma such as that associated with a coronary artery bypass grafting (CABG) procedure, especially when the CABG procedure involves extra-corporeal blood circulation, such as cardiopulmonary bypass (Bypass Apparatus). Arrows indicate activation from one component or event to another component or event in the cascade. Arrows in both directions indicate activating effects of components or events in both directions. Broken arrows indicate likely participation of one component or event in the activation of another component or event. Abbreviations: "tPA", tissue plasminogen activator; "C5a", a protein component of the complement system; "fXIIa", activator protein of prekallikrein to form active kallikrein; "Extrinsic", extrinsic coagulation system; "Intrinsic", intrinsic coagulation system.

Figure 2 shows a portion of a DNA and corresponding deduced amino acid for an exemplary kallikrein inhibitor polypeptide in plasmid pPIC-K503. The inserted DNA encodes the mat α Prepro signal peptide of *Saccharomyces cerevisiae* (underlined) fused in frame to the amino terminus of the PEP-1 polypeptide having the amino acid sequence enclosed by the boxed area. The amino acid sequence of the PEP-1 polypeptide shown in the boxed region is SEQ ID NO:2, and the corresponding nucleotide coding sequence is SEQ ID NO:3. The dashed arrows indicate the location and direction of two PCR primer sequences in *AOX* regions that were used to produce sequencing templates. DNA sequence for the entire nucleotide sequence of the figure includes the structural coding sequence for the fusion protein and is designated SEQ ID NO:27. The double underlined portion of the sequence indicates a diagnostic probe sequence. *Bst*B I and *Eco*R I indicate locations of their respective palindromic, hexameric, restriction endonuclease sites in the sequence. Asterisks denote translational stop codons. See text for details.

Figures 3A and 3B show an alignment of exemplary amino acid sequences, the native LACI sequence from which these variants were derived (SEQ ID NO:32), and other known Kunitz domains (SEQ ID NOS:29-31 and 33-53). Cysteine residues are highlighted.

Figure 4 is a graph depicting ischemic volume in C57B1/6 mice subjected to transient focal cerebral ischemia by middle cerebral artery occlusion (MCAO) using 5-0 microfilament and administered saline (control) or a kallikrein inhibitor polypeptide (DX-88) at various doses (10 μ g, 30 μ g, 90 μ g). The saline or kallikrein inhibitor polypeptide was administered at the beginning of the ischemic period.

Figure 5 is a graph depicting ischemic volume in C57B1/6 mice subjected to transient focal cerebral ischemia by middle cerebral artery occlusion (MCAO) using 6-0 microfilament and administered saline (control) or a kallikrein inhibitor polypeptide (DX-88) at various periods before and after ischemic damage. The kallikrein inhibitor polypeptide was administered at the beginning of the ischemic period (DX-88 pre), at the end of the ischemic period (DX-88 post), or at one hour after the beginning of the ischemic period (DX-88 1h post). The kallikrein inhibitor polypeptide was administered at 30 μ g.

Figure 6 is a graph depicting general neurological deficits in C57B1/6 mice subjected to transient focal cerebral ischemia by middle cerebral artery occlusion (MCAO) using 6-0 microfilament and administered saline (control) or a kallikrein inhibitor polypeptide (DX-88) at various periods before and after ischemic damage. The kallikrein inhibitor polypeptide was administered at the beginning of the ischemic period (DX-88 pre), at the end of the ischemic period (DX-88 post), or at one hour after the beginning of the ischemic period (DX-88 1h post). The kallikrein inhibitor polypeptide was administered at 30 μ g. General neurological deficits were measured based upon evaluation of the hair, ears, eyes, posture, spontaneous activity and epileptic behavior in the mice.

Figure 7 is a graph depicting focal neurological deficits in C57B1/6 mice subjected to transient focal cerebral ischemia by middle cerebral artery occlusion (MCAO) using 6-0 microfilament and administered saline (control) or a kallikrein inhibitor polypeptide (DX-88) at various periods before and after ischemic damage. The kallikrein inhibitor polypeptide was administered at the beginning of the ischemic period (DX-88 pre), at the end of the ischemic period (DX-88 post), or at one hour after the beginning of the ischemic period (DX-88 1h post). The kallikrein inhibitor polypeptide was administered at 30 μ g. Focal neurological deficits were measured based upon evaluation of the body symmetry, gait, climbing ability, circling behavior, front limb symmetry, compulsory circling and whisker response in the mice.

Figure 8 is a graph depicting the levels of a kallikrein activity found in the cerebral spinal fluid (CSF) of either untreated mice (normal CSF) or mice treated with a kallikrein inhibitor polypeptide (DX-88) at various doses (10 μ g or 30 μ g) measured at 30 or 60 minutes after administration.

5

DETAILED DESCRIPTION

The invention is based, in part, on the discovery that the use of a group of kallikrein inhibitor (KI) polypeptides that bind to and inhibit plasma kallikrein with a specificity, in combination with an anti-thrombolytic agent, e.g., an anti-fibrinolytic agent, provides improved methods of preventing or reducing blood loss, e.g., perioperative blood loss, e.g., in patients undergoing surgical procedures. The methods can also reduce or prevent injury associated with various ischemias and/or a systemic inflammatory response (SIR) in patients undergoing surgical procedures. Surgical procedures can include, e.g., a cardiothoracic surgery, (e.g., cardiopulmonary bypass (CPB) or coronary artery bypass grafting (CABG)); orthopedic surgery (e.g., hip or knee replacement or bone fracture); hepatectomy; nephrectomy; procedures that utilize extracorporeal circulation or dialysis; and any other procedure which can result in perioperative blood loss. "Blood loss" as used herein refers restoring blood supply and/or hemostasis, maintaining blood supply and/or hemostasis, and/or reducing the amount or need for a transfusion. For example, the methods, kits and compositions described herein can be used to reduce or prevent bleeding, capillary leakage and/or alterations in body fluid balance. Administered "in combination", as used herein, means that two (or more) different treatments are delivered to the subject while the subject is at risk for blood loss or during the course of the blood loss, e.g., the two or more treatments are delivered after the subject has been determined to be at risk for the disorder and before the disorder has been prevented, cured or eliminated or treatment has ceased for other reasons. In some embodiments, the delivery of one treatment is still occurring when the delivery of the second begins, so that there is overlap in terms of administration. This is sometimes referred to herein as "simultaneous" or "concurrent delivery." In other embodiments, the delivery of one treatment ends before the delivery of the other treatment begins. In some embodiments of either case, the treatment is more effective because of combined administration. For example, the anti-thrombolytic agent is more effective, e.g., an equivalent effect is seen with less of the anti-thrombolytic agent, the anti-thrombolytic

agent reduces symptoms to a greater extent than would be seen if the anti-thrombolytic agent were administered in the absence of the kallikrein inhibitor, and/or a side effect associated with the anti-thrombolytic agent is seen to a lesser extent than if the anti-thrombolytic agent were administered in the absence of the kallikrein inhibitor, or the analogous situation is seen with the kallikrein inhibitor. In some embodiments, delivery is such that the reduction in a symptom, or other parameter related to the disorder is greater than what would be observed with one treatment delivered in the absence of the other. The effect of the two treatments can be partially additive, wholly additive, or greater than additive. The delivery can be such that an effect of the first treatment delivered is still detectable when the second is delivered.

The combination treatment can be used to prevent or treat disorders associated with blood loss or blood fluidity. For example, the combination of a kallikrein inhibitor and an anti-thrombolytic agent can be used to treat or prevent perioperative blood loss, a systemic inflammatory response (SIR) induced by kallikrein (especially, for example, in patients undergoing surgical procedures and particularly surgical procedures involving cardiothoracic surgery, e.g., cardiopulmonary bypass (CPB), such as a coronary artery bypass graft (CABG) procedures as well as in patients with other disorders), cerebral ischemia and/or reperfusion injury associated with ischemia, e.g., cerebral ischemia.

Further examples of applications of the combination treatment include pediatric cardiac surgery, lung transplantation, total hip replacement and orthotopic liver transplantation, and to reduce or prevent perioperative stroke during CABG, extracorporeal membrane oxygenation (ECMO) and cerebrovascular accidents (CVA) during these procedures.

The kallikrein inhibitors described herein can also be used for stroke, e.g., embolism, thrombus and/or hemorrhage associated stroke and for reperfusion injury associated with stroke. In some embodiments, the kallikrein inhibitors are administered in combination with an anti-thrombolytic agent, e.g., an anti-fibrinolytic agent.

Cardiothoracic surgery is surgery of the chest area, most commonly the heart and lungs. Typical diseases treated by cardiothoracic surgery include coronary artery disease, tumors and cancers of the lung, esophagus and chest wall, heart vessel and valve abnormalities, and birth defects involving the chest or heart. Where

cardiothoracic surgery is utilized for treatment, the risk of blood loss (and, e.g., surgery-induced ischemia) and the onset of a systemic inflammatory response (SIR) is incurred. Surgery-induced SIR can result in severe organ dysfunction (systemic inflammatory response syndrome; SIRS).

5

Kunitz Domains

A number of useful inhibitors of kallikrein include a Kunitz domain.

As used herein, a "Kunitz domain" is a polypeptide domain having at least 51 amino acids and containing at least two, and preferably three, disulfides. The domain is folded such that the first and sixth cysteines, the second and fourth, and the third and fifth cysteines form disulfide bonds (e.g., in a Kunitz domain having 58 amino acids, cysteines can be present at positions corresponding to amino acids 5, 14, 30, 38, 51, and 55, according to the number of the BPTI homologous sequences provided below, and disulfides can form between the cysteines at position 5 and 55, 14 and 38, and 30 and 51), or, if two disulfides are present, they can form between a corresponding subset of cysteines thereof. The spacing between respective cysteines can be within 7, 5, 4, 3, 2, 1 or 0 amino acids of the following spacing between positions corresponding to: 5 to 55, 14 to 38, and 30 to 51, according to the numbering of the BPTI sequence provided below. The BPTI sequence can be used as a reference to refer to specific positions in any generic Kunitz domain. Comparison of a Kunitz domain of interest to BPTI can be performed by identifying the best fit alignment in which the number of aligned cysteines is maximized.

The 3D structure (at high resolution) of the Kunitz domain of BPTI is known. One of the X-ray structures is deposited in the Brookhaven Protein Data Bank as "6PTI". The 3D structure of some BPTI homologues (Eigenbrot *et al.*, (1990) Protein Engineering, 3(7):591-598; Hynes *et al.*, (1990) Biochemistry, 29:10018-10022) are known. At least eighty one Kunitz domain sequences are known. Known human homologues include three Kunitz domains of LACI (Wun *et al.*, (1988) J. Biol. Chem. 263(13):6001-6004; Girard *et al.*, (1989) Nature, 338:518-20; Novotny *et al.*, (1989) J. Biol. Chem., 264(31):18832-18837) two Kunitz domains of Inter- α -Trypsin Inhibitor, APP-I (Kido *et al.*, (1988) J. Biol. Chem., 263(34):18104-18107), a Kunitz domain from collagen, three Kunitz domains of TFPI-2 (Sprecher *et al.*, (1994) PNAS USA, 91:3353-3357), the Kunitz domains of hepatocyte growth factor activator

inhibitor type 1, the Kunitz domains of Hepatocyte growth factor activator inhibitor type 2, the Kunitz domains described in U.S. Patent Publication No.: 20040152633. LACI is a human serum phosphoglycoprotein with a molecular weight of 39 kDa (amino acid sequence in Table 1) containing three Kunitz domains.

5 **Table 1: Exemplary Natural Kunitz Domains**

LACI: (SEQ ID NO: 54)	1	MIYTMKKVHA LWASVCLLLN LAPAPLNAds eedehtiit dtelpplklm				
	51	HSFCAFKADD GPCKAIMKRF FFNIFTRQCE EFIYGGCEGN QNRFESLEEC				
	101	KKMCTRDnan riiktttlqge kpdfCfleeed pgiCrgyitr yfynnqtkqC				
	151	erfkyggClg nmnnfetlee CkniCedgpn gfqvdnygtq lnavnnsltp				
	201	qstkvpplfe fhgpswCltp adrglCrane nrfyynsvig kCrpfkysgC				
	251	ggnennftsk qeClraCkkg fiqriskggl iktkrkrkkq rvkiayeeif				
	301	vknm				
		The signal sequence (1-28) is uppercase and underscored				
		LACI-K1 (50-107) is uppercase				
		LACI-K2 (121-178) is underscored				
		LACI-K3 (211-270) is bold				
BPTI (SEQ ID NO: 55)	1	2	3	4	5	
	1234567890123456789012345678901234567890123456789012345678					
	RPDFCLEPPYTGPCKARIIRYFYNAKAGLCQTFVYGGCRAKRNNFKSAEDCMRTCGGA					

The Kunitz domains above are referred to as LACI-K1 (residues 50 to 107), LACI-K2 (residues 121 to 178), and LACI-K3 (213 to 270). The cDNA sequence of LACI is reported in Wun *et al.* (J. Biol. Chem., 1988, 263(13):6001-6004). Girard *et al.* (Nature, 1989, 338:518-20) reports mutational studies in which the P1 residues of each of the three Kunitz domains were altered. LACI-K1 inhibits Factor VIIa (F.VIIa) when F.VIIa is complexed to tissue factor and LACI-K2 inhibits Factor Xa.

Proteins containing exemplary Kunitz domains include the following, with SWISS-PROT Accession Numbers in parentheses:

- 15 A4_HUMAN (P05067), A4_MACFA (P53601), A4_MACMU (P29216),
A4_MOUSE (P12023), A4_RAT (P08592), A4_SAISC (Q95241),
AMBP_PLEPL (P36992), APP2_HUMAN (Q06481), APP2_RAT (P15943),
AXP1_ANTAF (P81547), AXP2_ANTAF (P81548), BPT1_BOVIN (P00974),
BPT2_BOVIN (P04815), CA17_HUMAN (Q02388), CA36_CHICK (P15989),
20 CA36_HUMAN (P12111), CRPT_BOOMI (P81162), ELAC_MACEU (O62845),
ELAC_TRIVU (Q29143), EPPI_HUMAN (O95925), EPPI_MOUSE (Q9DA01),
HTIB_MANSE (P26227), IBP_CARCR (P00993), IBPC_BOVIN (P00976),
IBPI_TACTR (P16044), IBPS_BOVIN (P00975), ICS3_BOMMO (P07481),
IMAP_DROFU (P11424), IP52_ANESU (P10280), ISC1_BOMMO (P10831),
25 ISC2_BOMMO (P10832), ISH1_STOHE (P31713), ISH2_STOHE (P81129),
ISIK_HELPO (P00994), ISP2_GALME (P81906), IVB1_BUNFA (P25660),
IVB1_BUNMU (P00987), IVB1_VIPAA (P00991), IVB2_BUNMU (P00989),
IVB2_DABRU (P00990), IVB2_HEMHA (P00985), IVB2_NAJNI (P00986),
IVB3_VIPAA (P00992), IVBB_DENPO (P00983), IVBC_NAJNA (P19859),
30 IVBC_OPHHA (P82966), IVBE_DENPO (P00984), IVBI_DENAN (P00980),
IVBI_DENPO (P00979), IVBK_DENAN (P00982), IVBK_DENPO (P00981),
IVBT_ERIMA (P24541), IVBT_NAJNA (P20229), MCPI_MELCP (P82968),
SBPI_SARBU (P26228), SPT3_HUMAN (P49223), TKD1_BOVIN (Q28201),

TKD1_SHEEP (Q29428), TXCA_DENAN (P81658), UPTI_PIG (Q29100),
 AMBP_BOVIN (P00978), AMBP_HUMAN (P02760), AMBP_MERUN (Q62577),
 AMBP_MESAU (Q60559), AMBP_MOUSE (Q07456), AMBP_PIG (P04366),
 AMBP_RAT (Q64240), IATR_HORSE (P04365), IATR_SHEEP (P13371),
 5 SPT1_HUMAN (O43278), SPT1_MOUSE (Q9R097), SPT2_HUMAN (O43291),
 SPT2_MOUSE (Q9WU03), TFP2_HUMAN (P48307), TFP2_MOUSE (O35536),
 TFPI_HUMAN (P10646), TFPI_MACMU (Q28864), TFPI_MOUSE (O54819),
 TFPI_RABBIT (P19761), TFPI_RAT (Q02445), YN81_CAEEL (Q03610)

10 A variety of methods can be used to identify a Kunitz domain from a sequence
 database. For example, a known amino acid sequence of a Kunitz domain, a
 consensus sequence, or a motif (e.g., the ProSite Motif) can be searched against the
 GenBank sequence databases (National Center for Biotechnology Information,
 National Institutes of Health, Bethesda MD), e.g., using BLAST; against Pfam
 15 database of HMMs (Hidden Markov Models) (e.g., using default parameters for Pfam
 searching; against the SMART database; or against the ProDom database. For
 example, the Pfam Accession Number PF00014 of Pfam Release 9 provides numerous
 Kunitz domains and an HMM for identify Kunitz domains. A description of the Pfam
 database can be found in Sonhammer *et al.* (1997) *Proteins* 28(3):405-420 and a
 20 detailed description of HMMs can be found, for example, in Gribskov *et al.* (1990)
Meth. Enzymol. 183:146-159; Gribskov *et al.* (1987) *Proc. Natl. Acad. Sci. USA*
 84:4355-4358; Krogh *et al.* (1994) *J. Mol. Biol.* 235:1501-1531; and Stultz *et al.*
 (1993) *Protein Sci.* 2:305-314. The SMART database (Simple Modular Architecture
 Research Tool, EMBL, Heidelberg, DE) of HMMs as described in Schultz *et al.*
 25 (1998), *Proc. Natl. Acad. Sci. USA* 95:5857 and Schultz *et al.* (2000) *Nucl. Acids Res*
 28:231. The SMART database contains domains identified by profiling with the
 hidden Markov models of the HMMer2 search program (R. Durbin *et al.* (1998)
Biological sequence analysis: probabilistic models of proteins and nucleic acids.
 Cambridge University Press). The database also is annotated and monitored. The
 30 ProDom protein domain database consists of an automatic compilation of homologous
 domains (Corpet *et al.* (1999), *Nucl. Acids Res.* 27:263-267). Current versions of
 ProDom are built using recursive PSI-BLAST searches (Altschul *et al.* (1997) *Nucleic*
Acids Res. 25:3389-3402; Gouzy *et al.* (1999) *Computers and Chemistry* 23:333-340.)
 of the SWISS-PROT 38 and TREMBL protein databases. The database automatically
 35 generates a consensus sequence for each domain. Prosite lists the Kunitz domain as a
 motif and identifies proteins that include a Kunitz domain. See, e.g., Falquet *et al.*
Nucleic Acids Res. 30:235-238(2002).

Kunitz domains interact with target protease using, primarily, amino acids in two loop regions ("binding loops"). The first loop region is between about residues corresponding to amino acids 13-20 of BPTI. The second loop region is between about residues corresponding to amino acids 31-39 of BPTI. An exemplary library of Kunitz domains varies one or more amino acid positions in the first and/or second loop regions. Particularly useful positions to vary, when screening for Kunitz domains that interact with kallikrein or when selecting for improved affinity variants, include: positions 13, 15, 16, 17, 18, 19, 31, 32, 34, and 39 with respect to the sequence of BPTI. At least some of these positions are expected to be in close contact with the target protease. It is also useful to vary other positions, e.g., positions that are adjacent to the aforementioned positions in the three-dimensional structure.

The "framework region" of a Kunitz domain is defined as those residues that are a part of the Kunitz domain, but specifically excluding residues in the first and second binding loops regions, i.e., about residues corresponding to amino acids 13-20 of BPTI and 31-39 of BPTI. Conversely, residues that are not in the binding loop may tolerate a wider range of amino acid substitution (e.g., conservative and/or non-conservative substitutions).

In one embodiment, these Kunitz domains are variant forms of the looped structure including Kunitz domain 1 of human lipoprotein-associated coagulation inhibitor (LACI) protein. LACI contains three internal, well-defined, peptide loop structures that are paradigm Kunitz domains (Girard, T. et al., 1989. *Nature*, 338:518-520). Variants of Kunitz domain 1 of LACI described herein have been screened, isolated and bind kallikrein with enhanced affinity and specificity (see, for example, U.S. Pat. Nos. 5,795,865 and 6,057,287, incorporated herein by reference). These methods can also be applied to other Kunitz domain frameworks to obtain other Kunitz domains that interact with kallikrein, e.g., plasma kallikrein. Useful modulators of kallikrein function typically bind and/or inhibit kallikrein, as determined using kallikrein binding and inhibition assays.

An exemplary polypeptide that includes a Kunitz domain that inhibits kallikrein has the amino acid sequence defined by amino acids 3-60 of SEQ ID NO:2.

An exemplary polypeptide includes the amino acid sequence:

Xaa1 Xaa2 Xaa3 Xaa4 Cys Xaa6 Xaa7 Xaa8 Xaa9 Xaa10 Xaa11 Gly Xaa13
Cys Xaa15 Xaa16 Xaa17 Xaa18 Xaa19 Xaa20 Xaa21 Xaa22 Xaa23 Xaa24 Xaa25
Xaa26 Xaa27 Xaa28 Xaa29 Cys Xaa31 Xaa32 Phe Xaa34 Xaa35 Gly Gly Cys Xaa39

Xaa40 Xaa41 Xaa42 Xaa43 Xaa44 Xaa45 Xaa46 Xaa47 Xaa48 Xaa49 Xaa50 Cys
Xaa52 Xaa53 Xaa54 Cys Xaa56 Xaa57 Xaa58 (SEQ ID NO:1)

"Xaa" refers to a position in a peptide chain that can be any of a number of different amino acids. In a first example, Xaa can be any amino acid except cysteine.

5 In another example, one or more of the following apply: Xaa10 can be Asp or Glu; Xaa11 can be Asp, Gly, Ser, Val, Asn, Ile, Ala or Thr; Xaa13 can be Pro, Arg, His, Asn, Ser, Thr, Ala, Gly, Lys or Gln; Xaa15 can be Arg, Lys, Ala, Ser, Gly, Met, Asn or Gln; Xaa16 can be Ala, Gly, Ser, Asp or Asn; Xaa17 can be Ala, Asn, Ser, Ile, Gly, Val, Gln or Thr; Xaa18 can be His, Leu, Gln or Ala; Xaa19 can be Pro, Gln, Leu, Asn
10 or Ile; Xaa21 can be Trp, Phe, Tyr, His or Ile; Xaa31 can be Glu, Asp, Gln, Asn, Ser, Ala, Val, Leu, Ile or Thr; Xaa32 can be Glu, Gln, Asp, Asn, Pro, Thr, Leu, Ser, Ala, Gly or Val; Xaa34 can be Ile, Thr, Ser, Val, Ala, Asn, Gly or Leu; Xaa35 can be Tyr, Trp or Phe; Xaa39 can be Glu, Gly, Ala, Ser or Asp. Amino acids Xaa6, Xaa7, Xaa8, Xaa9, Xaa20, Xaa24, Xaa25, Xaa26, Xaa27, Xaa28, Xaa29, Xaa41, Xaa42, Xaa44,
15 Xaa46, Xaa47, Xaa48, Xaa49, Xaa50, Xaa52, Xaa53 and Xaa54 can be any amino acid.

Additionally, each of the first four and at last three amino acids of SEQ ID NO:1 can optionally be present or absent and can be any amino acid, if present, e.g., any non-cysteine amino acid.

20 In one embodiment, the polypeptide has a sequence with one or more of the following properties: Xaa11 can be Asp, Gly, Ser or Val; Xaa13 can be Pro, Arg, His or Asn; Xaa15 can be Arg or Lys; Xaa16 can be Ala or Gly; Xaa17 can be Ala, Asn, Ser or Ile; Xaa18 can be His, Leu or Gln; Xaa19 can be Pro, Gln or Leu; Xaa21 can be Trp or Phe; Xaa31 is Glu; Xaa32 can be Glu or Gln; Xaa34 can be Ile, Thr or Ser;
25 Xaa35 is Tyr; and Xaa39 can be Glu, Gly or Ala.

An exemplary polypeptide can include the following amino acids: Xaa10 is Asp; Xaa11 is Asp; Xaa13 can be Pro or Arg; Xaa15 is Arg; Xaa16 can be Ala or Gly; Xaa17 is Ala; Xaa18 is His; Xaa19 is Pro; Xaa21 is Trp; Xaa31 is Glu; Xaa32 is Glu; Xaa34 can be Ile or Ser; Xaa35 is Tyr; and Xaa39 is Gly.

30 It is also possible to use portions of the polypeptides described herein. For example, polypeptides could include binding domains for specific kallikrein epitopes. For example, the binding loops of Kunitz domains can be cyclized and used in isolation or can be grafted onto another domain, e.g., a framework of another Kunitz domain. It is also possible to remove one, two, three, or four amino acids from the N-

terminus of an amino acid sequence described herein, and/or one, two, three, four, or five amino acids from the C-terminus of an amino acid sequence described herein.

Examples of sequences encompassed by SEQ ID NO:1 are described by the following (where not indicated, "Xaa" refers to any amino acid, any non-cysteine

5 amino acid or any amino acid from the same set of amino acids that are allowed for SEQ ID NO:1):

Met His Ser Phe Cys Ala Phe Lys Ala Xaa10 Xaa11 Gly Xaa13 Cys Xaa15
Xaa16 Xaa17 Xaa18 Xaa19 Arg Xaa21 Phe Phe Asn Ile Phe Thr Arg Gln Cys Xaa31
Xaa32 Phe Xaa34 Xaa35 Gly Gly Cys Xaa39 Gly Asn Gln Asn Arg Phe Glu Ser Leu
10 Glu Glu Cys Lys Lys Met Cys Thr Arg Asp (SEQ ID NO:56).

Met His Ser Phe Cys Ala Phe Lys Ala Asp Asp Gly Pro Cys Arg Ala Ala His
Pro Arg Trp Phe Phe Asn Ile Phe Thr Arg Gln Cys Glu Glu Phe Ile Tyr Gly Gly Cys
Glu Gly Asn Gln Asn Arg Phe Glu Ser Leu Glu Glu Cys Lys Lys Met Cys Thr Arg
15 Asp (amino acids 3-60 of SEQ ID NO:2),

Met His Ser Phe Cys Ala Phe Lys Ala Asp Asp Gly Pro Cys Lys Ala Asn His
Leu Arg Phe Phe Phe Asn Ile Phe Thr Arg Gln Cys Glu Glu Phe Ser Tyr Gly Gly Cys
Gly Gly Asn Gln Asn Arg Phe Glu Ser Leu Glu Glu Cys Lys Lys Met Cys Thr Arg
20 Asp (SEQ ID NO:4),

Met His Ser Phe Cys Ala Phe Lys Ala Asp Asp Gly His Cys Lys Ala Asn His
Gln Arg Phe Phe Phe Asn Ile Phe Thr Arg Gln Cys Glu Glu Phe Thr Tyr Gly Gly Cys
Gly Gly Asn Gln Asn Arg Phe Glu Ser Leu Glu Glu Cys Lys Lys Met Cys Thr Arg
25 Asp (SEQ ID NO:5),

Met His Ser Phe Cys Ala Phe Lys Ala Asp Asp Gly His Cys Lys Ala Asn His
Gln Arg Phe Phe Phe Asn Ile Phe Thr Arg Gln Cys Glu Gln Phe Thr Tyr Gly Gly Cys
Ala Gly Asn Gln Asn Arg Phe Glu Ser Leu Glu Glu Cys Lys Lys Met Cys Thr Arg
30 Asp (SEQ ID NO:6),

Met His Ser Phe Cys Ala Phe Lys Ala Asp Asp Gly His Cys Lys Ala Ser Leu
Pro Arg Phe Phe Phe Asn Ile Phe Thr Arg Gln Cys Glu Glu Phe Ile Tyr Gly Gly Cys

Gly Gly Asn Gln Asn Arg Phe Glu Ser Leu Glu Glu Cys Lys Lys Met Cys Thr Arg
Asp (SEQ ID NO:7),

Met His Ser Phe Cys Ala Phe Lys Ala Asp Asp Gly His Cys Lys Ala Asn His
5 Gln Arg Phe Phe Phe Asn Ile Phe Thr Arg Gln Cys Glu Glu Phe Ser Tyr Gly Gly Cys
Gly Gly Asn Gln Asn Arg Phe Glu Ser Leu Glu Glu Cys Lys Lys Met Cys Thr Arg
Asp (SEQ ID NO:8),

Met His Ser Phe Cys Ala Phe Lys Ala Asp Asp Gly His Cys Lys Gly Ala His
10 Leu Arg Phe Phe Phe Asn Ile Phe Thr Arg Gln Cys Glu Glu Phe Ile Tyr Gly Gly Cys
Glu Gly Asn Gln Asn Arg Phe Glu Ser Leu Glu Glu Cys Lys Lys Met Cys Thr Arg
Asp (SEQ ID NO:9),

Met His Ser Phe Cys Ala Phe Lys Ala Asp Asp Gly Arg Cys Lys Gly Ala His
15 Leu Arg Phe Phe Phe Asn Ile Phe Thr Arg Gln Cys Glu Glu Phe Ile Tyr Gly Gly Cys
Glu Gly Asn Gln Asn Arg Phe Glu Ser Leu Glu Glu Cys Lys Lys Met Cys Thr Arg
Asp (SEQ ID NO:10),

Met His Ser Phe Cys Ala Phe Lys Ala Asp Asp Gly Gly Arg Cys Arg Gly Ala His
20 Pro Arg Trp Phe Phe Asn Ile Phe Thr Arg Gln Cys Glu Glu Phe Ser Tyr Gly Gly Cys
Gly Gly Asn Gln Asn Arg Phe Glu Ser Leu Glu Glu Cys Lys Lys Met Cys Thr Arg
Asp (SEQ ID NO:11),

Met His Ser Phe Cys Ala Phe Lys Ala Asp Asp Gly Pro Cys Arg Ala Ala His
25 Pro Arg Trp Phe Phe Asn Ile Phe Thr Arg Gln Cys Glu Glu Phe Ser Tyr Gly Gly Cys
Gly Gly Asn Gln Asn Arg Phe Glu Ser Leu Glu Glu Cys Lys Lys Met Cys Thr Arg
Asp (SEQ ID NO:12),

Met His Ser Phe Cys Ala Phe Lys Ala Asp Val Gly Arg Cys Arg Gly Ala His
30 Pro Arg Trp Phe Phe Asn Ile Phe Thr Arg Gln Cys Glu Glu Phe Ser Tyr Gly Gly Cys
Gly Gly Asn Gln Asn Arg Phe Glu Ser Leu Glu Glu Cys Lys Lys Met Cys Thr Arg
Asp (SEQ ID NO:13),

Met His Ser Phe Cys Ala Phe Lys Ala Asp Val Gly Arg Cys Arg Gly Ala Gln
Pro Arg Phe Phe Phe Asn Ile Phe Thr Arg Gln Cys Glu Glu Phe Ser Tyr Gly Gly Cys
Gly Gly Asn Gln Asn Arg Phe Glu Ser Leu Glu Glu Cys Lys Lys Met Cys Thr Arg
Asp (SEQ ID NO: 14),

5

Met His Ser Phe Cys Ala Phe Lys Ala Asp Asp Gly Ser Cys Arg Ala Ala His
Leu Arg Trp Phe Phe Asn Ile Phe Thr Arg Gln Cys Glu Glu Phe Ser Tyr Gly Gly Cys
Gly Gly Asn Gln Asn Arg Phe Glu Ser Leu Glu Glu Cys Lys Lys Met Cys Thr Arg
Asp (SEQ ID NO:15),

10

Met His Ser Phe Cys Ala Phe Lys Ala Glu Gly Gly Ser Cys Arg Ala Ala His
Gln Arg Trp Phe Phe Asn Ile Phe Thr Arg Gln Cys Glu Glu Phe Ser Tyr Gly Gly Cys
Gly Gly Asn Gln Asn Arg Phe Glu Ser Leu Glu Glu Cys Lys Lys Met Cys Thr Arg
Asp (SEQ ID NO:16),

15

Met His Ser Phe Cys Ala Phe Lys Ala Asp Asp Gly Pro Cys Arg Gly Ala His
Leu Arg Phe Phe Phe Asn Ile Phe Thr Arg Gln Cys Glu Glu Phe Ser Tyr Gly Gly Cys
Gly Gly Asn Gln Asn Arg Phe Glu Ser Leu Glu Glu Cys Lys Lys Met Cys Thr Arg
Asp (SEQ ID NO:17),

20

Met His Ser Phe Cys Ala Phe Lys Ala Asp Asp Gly His Cys Arg Gly Ala Leu
Pro Arg Trp Phe Phe Asn Ile Phe Thr Arg Gln Cys Glu Glu Phe Ser Tyr Gly Gly Cys
Gly Gly Asn Gln Asn Arg Phe Glu Ser Leu Glu Glu Cys Lys Lys Met Cys Thr Arg
Asp (SEQ ID NO:18),

25

Met His Ser Phe Cys Ala Phe Lys Ala Asp Ser Gly Asn Cys Arg Gly Asn Leu
Pro Arg Phe Phe Phe Asn Ile Phe Thr Arg Gln Cys Glu Glu Phe Ser Tyr Gly Gly Cys
Gly Gly Asn Gln Asn Arg Phe Glu Ser Leu Glu Glu Cys Lys Lys Met Cys Thr Arg
Asp (SEQ ID NO:19),

30

Met His Ser Phe Cys Ala Phe Lys Ala Asp Ser Gly Arg Cys Arg Gly Asn His
Gln Arg Phe Phe Phe Asn Ile Phe Thr Arg Gln Cys Glu Glu Phe Ser Tyr Gly Gly Cys
Gly Gly Asn Gln Asn Arg Phe Glu Ser Leu Glu Glu Cys Lys Lys Met Cys Thr Arg

Asp (SEQ ID NO:20),

Met His Ser Phe Cys Ala Phe Lys Ala Asp Gly Gly Arg Cys Arg Ala Ile Gln
Pro Arg Trp Phe Phe Asn Ile Phe Thr Arg Gln Cys Glu Glu Phe Ser Tyr Gly Gly Cys
5 Gly Gly Asn Gln Asn Arg Phe Glu Ser Leu Glu Glu Cys Lys Lys Met Cys Thr Arg
Asp (SEQ ID NO:21),

Met His Ser Phe Cys Ala Phe Lys Ala Asp Asp Gly Arg Cys Arg Gly Ala His
Pro Arg Trp Phe Phe Asn Ile Phe Thr Arg Gln Cys Glu Glu Phe Ser Tyr Gly Gly Cys
10 Gly Gly Asn Gln Asn Arg Phe Glu Ser Leu Glu Glu Cys Lys Lys Met Cys Thr Arg
Asp (SEQ ID NO:22).

Additional examples of sequence include those that differ by at least one
amino acid, but fewer than seven, six, five, four, three, or two amino acids differences
15 relative to an amino acid sequence described herein, e.g., an amino acid sequence
provided above. In one embodiment, fewer than three, two, or one differences are in
one of the binding loops. For example, the first binding loop may have no differences
relative to an amino acid sequence described herein, e.g., an amino acid sequence
provided above. In another example, neither the first nor the second binding loop
20 differs from an amino acid sequence described herein, e.g., an amino acid sequence
provided above.

FIGS. 3A and 3B provides an amino acid sequence alignment of these
sequences, the native LACI sequence from which these variants were derived (SEQ
ID NO:32), and other known Kunitz domains (SEQ ID NOS: 29-31 and 33-53). Still
25 others polypeptides that inhibit kallikrein include an about 58-amino acid sequence of
amino acids 3-60 of SEQ ID NO:2 or the PEP-1 polypeptide having the 60-amino
acid sequence of SEQ ID NO:2. The term "PEP-1" and "DX-88" as used herein refer
to the 60-amino acid sequence of SEQ ID NO:2. A nucleotide sequence encoding the
amino acid sequence of SEQ ID NO:2 is provided in SEQ ID NO:3 (see, e.g.,
30 nucleotides 309-488 in FIG. 2). It is understood that based on the known genetic
code, degenerate forms of the nucleotide sequence of SEQ ID NO:3 can be obtained
by simply substituting one or more of the known degenerate codons for each amino
acid encoded by the nucleotide sequence. Nucleotides 7-180 of SEQ ID NO:3, and
degenerate forms thereof, encode the non-naturally occurring Kunitz domain

polypeptide that includes the 58-amino acid sequence of amino acids 3-60 of SEQ ID NO:2, a related sequence, or a functional fragment thereof.

In one embodiment, the polypeptide is other than aprotinin, e.g., differs from aprotinin, by at least one, two, three, five, ten, or fifteen amino acids.

5 Polypeptides described herein can be made synthetically using any standard polypeptide synthesis protocol and equipment. For example, the stepwise synthesis of a polypeptide can be carried out by the removal of an amino (N) terminal-protecting group from an initial (i.e., carboxy-terminal) amino acid, and coupling thereto of the carboxyl end of the next amino acid in the sequence of the polypeptide. This amino
10 acid is also suitably protected. The carboxyl group of the incoming amino acid can be activated to react with the N-terminus of the bound amino acid by formation into a reactive group such as formation into a carbodiimide, a symmetric acid anhydride, or an "active ester" group such as hydroxybenzotriazole or pentafluorophenyl esters. Preferred solid-phase peptide synthesis methods include the BOC method, which
15 utilizes tert-butyloxycarbonyl as the α -amino protecting group, and the Fmoc method, which utilizes 9-fluorenylmethoxycarbonyl to protect the alpha-amino of the amino acid residues. Both methods are well known to those of skill in the art (Stewart, J. and Young, J., Solid-Phase Peptide Synthesis (W. H. Freeman Co., San Francisco 1989); Merrifield, J., 1963. Am. Chem. Soc., 85:2149-2154; Bodanszky, M. and Bodanszky, A., The Practice of Peptide Synthesis (Springer-Verlag, New
20 York 1984)). If desired, additional amino- and/or carboxy-terminal amino acids can be designed into the amino acid sequence and added during polypeptide synthesis.

Polypeptides can also be produced using recombinant technology. Recombinant methods can employ any of a number of cells and corresponding
25 expression vectors, including but not limited to bacterial expression vectors, yeast expression vectors, baculovirus expression vectors, mammalian viral expression vectors, and the like. A polypeptide described herein can be produced by a transgenic animal, e.g., in the mammary gland of a transgenic animal. In some cases, it could be necessary or advantageous to fuse the coding sequence for a polypeptide that inhibits
30 kallikrein (e.g., a polypeptide that includes a Kunitz domain) to another coding sequence in an expression vector to form a fusion polypeptide that is readily expressed in a host cell. Part or all of the additional sequence can be removed, e.g., by protease digestion.

An exemplary recombinant expression system for producing a polypeptide that inhibits kallikrein (e.g., a polypeptide that includes a Kunitz domain) is a yeast expression vector, which permits a nucleic acid sequence encoding the amino acid sequence for the inhibitor polypeptide to be linked in the same reading frame with a
5 nucleotide sequence encoding the MAT α prepro leader peptide sequence of *Saccharomyces cerevisiae*, which in turn is under the control of an operable yeast promoter. The resulting recombinant yeast expression plasmid can be transformed by standard methods into the cells of an appropriate, compatible yeast host, which cells are able to express the recombinant protein from the recombinant yeast expression
10 vector. Preferably, a host yeast cell transformed with such a recombinant expression vector is also able to process the fusion protein to provide an active inhibitor polypeptide. An other exemplary yeast host for producing recombinant polypeptides is *Pichia pastoris*.

As noted above, polypeptides that inhibit kallikrein can include a Kunitz
15 domain polypeptide described herein. Some polypeptides can include an additional flanking sequence, preferably of one to six amino acids in length, at the amino and/or carboxy-terminal end, provided such additional amino acids do not significantly diminish kallikrein binding affinity or kallikrein inhibition activity so as to preclude use in the methods and compositions described herein. Such additional amino acids
20 can be deliberately added to express a polypeptide in a particular recombinant host cell or can be added to provide an additional function, e.g., to provide a linker to another molecule or to provide an affinity moiety that facilitates purification of the polypeptide. Preferably, the additional amino acid(s) do not include cysteine, which could interfere with the disulfide bonds of the Kunitz domain.

25 An exemplary Kunitz domain polypeptide includes the amino acid sequence of residues 3-60 of SEQ ID NO:2. When expressed and processed in a yeast fusion protein expression system (e.g., based on the integrating expression plasmid pHIL-D2), such a Kunitz domain polypeptide retains an additional amino terminal Glu-Ala dipeptide from the fusion with the MAT α -prepro leader peptide sequence of *S.*
30 *cerevisiae*. When secreted from the yeast host cell, most of the leader peptide is processed from the fusion protein to yield a functional polypeptide (referred to herein as "PEP-1") having the amino acid sequence of SEQ ID NO:2 (see boxed region in FIG. 2).

In one embodiment, an inhibitor of kallikrein, e.g., a polypeptide inhibitor, has a binding affinity for kallikrein that is on the order of 1000 times higher than that of aprotinin, which is currently approved for use in CABG procedures to reduce blood loss. The surprisingly high binding affinities of such kallikrein inhibitors combined
5 with their high degree of specificity for kallikrein to the exclusion of other molecular targets (see Table 1, below) provide for particularly useful inhibitors. However, inhibitors with lesser affinity or specificity also have their applications.

A typical Kunitz domain, e.g., that includes, SEQ ID NO:1, contains a number of invariant positions, e.g., positions corresponding to position 5, 14, 30, 33, 38, 45,
10 51 and 55 in the BPTI numbering scheme are cysteine. The spacing between these positions may vary to the extent allowable within the Kunitz domain fold, e.g., such that three disulfide bonds are formed. Other positions such as, for example, positions 6, 7, 8, 9, 20, 24, 25, 26, 27, 28, 29, 41, 42, 44, 46, 47, 48, 49, 50, 52, 53 and 54, or positions corresponding to those positions, can be any amino acid (including non-
15 genetically encoded occurring amino acids). In a particularly preferred embodiment, one or more amino acids correspond to that of a native sequence (e.g., SEQ ID NO:32, see FIG. 3). In another embodiment, at least one variable position is different from that of the native sequence. In yet another preferred embodiment, the amino acids can each be individually or collectively substituted by a conservative or non-
20 conservative amino acid substitution.

Conservative amino acid substitutions replace an amino acid with another amino acid of similar chemical nature and may have no affect on protein function. Non-conservative amino acid substitutions replace an amino acid with another amino acid of dissimilar chemical structure. Examples of conserved amino acid substitutions
25 include, for example, Asn->Gln, Arg->Lys and Ser->Thr. In a preferred embodiment, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20 and/or 21 of these amino acids can be independently or collectively, in any combination, selected to correspond to the corresponding position of SEQ ID NO:2.

Other positions, for example, positions 10, 11, 13, 15, 16, 17, 18, 19, 21, 22,
30 23, 31, 32, 34, 35, 39, 40, 43 and 45, or positions corresponding to those positions can be any of a selected set of amino acids. For example, SEQ ID NO:1 defines a set of possible sequences. Each member of this set contains, for example, a cysteine at positions 5, 14, 30, 51 and 55, and any one of a specific set of amino acids at positions 10, 11, 13, 15, 16, 17, 18, 19, 21, 22, 23, 31, 32, 34, 35, 39, 40, 43 and 45, or

positions corresponding to those positions. In a preferred embodiment, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18 and/or 19 of these amino acids can be independently or collectively, in any combination, selected to correspond to the corresponding position of SEQ ID NO:2. The polypeptide preferably has at least
5 80%, 85%, 90%, 95, 97, 98, or 99% identity to SEQ ID NO:2.

As used herein, the term "substantially identical" (or "substantially homologous") is used herein to refer to a first amino acid or nucleotide sequence that contains a sufficient number of identical or equivalent (e.g., with a similar side chain, e.g., conserved amino acid substitutions) amino acid residues or nucleotides to a
10 second amino acid or nucleotide sequence such that the first and second amino acid or nucleotide sequences have similar activities. In the case of antibodies, the second antibody has the same specificity and has at least 50% of the affinity of the same.

Calculations of "homology" between two sequences can be performed as follows. The sequences are aligned for optimal comparison purposes (e.g., gaps can
15 be introduced in one or both of a first and a second amino acid or nucleic acid sequence for optimal alignment and non-homologous sequences can be disregarded for comparison purposes). In a preferred embodiment, the length of a reference sequence aligned for comparison purposes is at least 30%, preferably at least 40%, more preferably at least 50%, even more preferably at least 60%, and even more
20 preferably at least 70%, 80%, 90%, 100% of the length of the reference sequence. The amino acid residues or nucleotides at corresponding amino acid positions or nucleotide positions are then compared. When a position in the first sequence is occupied by the same amino acid residue or nucleotide as the corresponding position in the second sequence, then the molecules are identical at that position (as used
25 herein amino acid or nucleic acid "identity" is equivalent to amino acid or nucleic acid "homology"). The percent identity between the two sequences is a function of the number of identical positions shared by the sequences, taking into account the number of gaps, and the length of each gap, which need to be introduced for optimal alignment of the two sequences.

30 The comparison of sequences and determination of percent homology between two sequences can be accomplished using a mathematical algorithm. In a preferred embodiment, the percent homology between two amino acid sequences is determined using the Needleman and Wunsch (1970), J. Mol. Biol. 48:444-453, algorithm which has been incorporated into the GAP program in the GCG software package, using

either a Blossum 62 matrix or a PAM250 matrix, and a gap weight of 16, 14, 12, 10, 8, 6, or 4 and a length weight of 1, 2, 3, 4, 5, or 6. In yet another preferred embodiment, the percent homology between two nucleotide sequences is determined using the GAP program in the GCG software package, using a NWSgapdna.CMP
5 matrix and a gap weight of 40, 50, 60, 70, or 80 and a length weight of 1, 2, 3, 4, 5, or 6. A particularly preferred set of parameters (and the one that should be used if the practitioner is uncertain about what parameters should be applied to determine if a molecule is within a homology limitation) are a Blossum 62 scoring matrix with a gap penalty of 12, a gap extend penalty of 4, and a frameshift gap penalty of 5.

10 Useful polypeptides can also be encoded by a nucleic acid that hybridizes to a nucleic acid that encodes a polypeptide described herein. The nucleic acids can hybridize under medium, high, or very high stringency conditions. As used herein, the term "hybridizes under low stringency, medium stringency, high stringency, or very high stringency conditions" describes conditions for hybridization and washing.
15 Guidance for performing hybridization reactions can be found in *Current Protocols in Molecular Biology*, John Wiley & Sons, N.Y. (1989), 6.3.1-6.3.6, which is incorporated by reference. Aqueous and nonaqueous methods are described in that reference and either can be used. Specific hybridization conditions referred to herein are as follows: (1) low stringency hybridization conditions in 6X sodium
20 chloride/sodium citrate (SSC) at about 45°C, followed by two washes in 0.2X SSC, 0.1% SDS at least at 50°C (the temperature of the washes can be increased to 55°C for low stringency conditions); (2) medium stringency hybridization conditions in 6X SSC at about 45°C, followed by one or more washes in 0.2X SSC, 0.1% SDS at 60°C; (3) high stringency hybridization conditions in 6X SSC at about 45°C, followed by
25 one or more washes in 0.2X SSC, 0.1% SDS at 65°C; and (4) very high stringency hybridization conditions are 0.5M sodium phosphate, 7% SDS at 65°C, followed by one or more washes at 0.2X SSC, 1% SDS at 65°C.

Modifications

It is possible to modify polypeptides that inhibit a Kunitz domain in a variety
30 of ways. For example, the polypeptides can be attached to one or more polyethylene glycol moieties to stabilize the compound or prolong retention times, e.g., by at least 2, 4, 5, 8, 10, 15, 20, 50, 100, 500 or 1000 fold.

A polypeptide that inhibits kallikrein can be associated with (e.g., conjugated to) a polymer, e.g., a substantially non-antigenic polymers, such as polyalkylene oxides or polyethylene oxides. Suitable polymers will vary substantially by weight. Polymers having molecular number average weights ranging from about 200 to about 5 35,000 (or about 1,000 to about 15,000, and 2,000 to about 12,500) can be used. A plurality of polymer moieties can be attached to one polypeptide, e.g., at least two, three, or four such moieties, e.g., having an average molecular weight of about 2,000 to 7,000 Daltons.

For example, the polypeptide can be conjugated to a water soluble polymer, 10 e.g., hydrophilic polyvinyl polymers, e.g. polyvinylalcohol and polyvinylpyrrolidone.. A non-limiting list of such polymers include polyalkylene oxide homopolymers such as polyethylene glycol (PEG) or polypropylene glycols, polyoxyethylenated polyols, copolymers thereof and block copolymers thereof, provided that the water solubility of the block copolymers is maintained. Additional useful polymers include 15 polyoxyalkylenes such as polyoxyethylene, polyoxypropylene, and block copolymers of polyoxyethylene and polyoxypropylene (Pluronic); polymethacrylates; carbomers; branched or unbranched polysaccharides which comprise the saccharide monomers D-mannose, D- and L-galactose, fucose, fructose, D-xylose, L-arabinose, D-glucuronic acid, sialic acid, D-galacturonic acid, D-mannuronic acid (e.g. 20 polymannuronic acid, or alginic acid), D-glucosamine, D-galactosamine, D-glucose and neuraminic acid including homopolysaccharides and heteropolysaccharides such as lactose, amylopectin, starch, hydroxyethyl starch, amylose, dextrane sulfate, dextran, dextrans, glycogen, or the polysaccharide subunit of acid mucopolysaccharides, e.g. hyaluronic acid; polymers of sugar alcohols such as 25 polysorbitol and polymannitol; heparin or heparan.

Other compounds can also be attached to the same polymer, e.g., a cytotoxin, a label, or another targeting agent or an unrelated agent. Mono-activated, alkoxy-terminated polyalkylene oxides (PAO's), e.g., monomethoxy-terminated polyethylene glycols (mPEG's); C₁₋₄ alkyl-terminated polymers; and bis-activated polyethylene 30 oxides (glycols) can be used for crosslinking. See, e.g., U.S. 5,951,974.

Kallikrein Inhibitors- Antibodies

One class of kallikrein inhibitors includes antibodies. Exemplary antibodies bind, e.g., specifically to kallikrein, e.g., plasma kallikrein. An antibody can inhibit kallikrein in a number of ways. For example, it can contact one or more residues of the active site, sterically hinder or obstruct access to the active site, prevent maturation of kallikrein, or destabilize a conformation required for catalytic activity. Such antibodies can be used, e.g., to reduce or prevent reperfusion injury, e.g., reperfusion injury associated with cerebral ischemia, in a patient.

As used herein, the term “antibody” refers to a protein that includes at least one immunoglobulin variable domain or immunoglobulin variable domain sequence. For example, an antibody can include a heavy (H) chain variable region (abbreviated herein as VH), and a light (L) chain variable region (abbreviated herein as VL). In another example, an antibody includes two heavy (H) chain variable regions and two light (L) chain variable regions. The term “antibody” encompasses antigen-binding fragments of antibodies (e.g., single chain antibodies, Fab fragments, F(ab')₂, a Fd fragment, a Fv fragments, and dAb fragments) as well as complete antibodies.

The VH and VL regions can be further subdivided into regions of hypervariability, termed “complementarity determining regions” (“CDR”), interspersed with regions that are more conserved, termed “framework regions” (FR). The extent of the framework region and CDR's has been precisely defined (see, Kabat, E.A., *et al.* (1991) *Sequences of Proteins of Immunological Interest, Fifth Edition*, U.S. Department of Health and Human Services, NIH Publication No. 91-3242, and Chothia, C. *et al.* (1987) *J. Mol. Biol.* 196:901-917). Kabat definitions are used herein. Each VH and VL is typically composed of three CDR's and four FR's, arranged from amino-terminus to carboxy-terminus in the following order: FR1, CDR1, FR2, CDR2, FR3, CDR3, FR4.

An “immunoglobulin domain” refers to a domain from the variable or constant domain of immunoglobulin molecules. Immunoglobulin domains typically contain two β -sheets formed of about seven β -strands, and a conserved disulphide bond (see, e.g., A. F. Williams and A. N. Barclay 1988 *Ann. Rev Immunol.* 6:381-405).

As used herein, an “immunoglobulin variable domain sequence” refers to an amino acid sequence which can form the structure of an immunoglobulin variable domain. For example, the sequence may include all or part of the amino acid

sequence of a naturally-occurring variable domain. For example, the sequence may omit one, two or more N- or C-terminal amino acids, internal amino acids, may include one or more insertions or additional terminal amino acids, or may include other alterations. In one embodiment, a polypeptide that includes immunoglobulin
5 variable domain sequence can associate with another immunoglobulin variable domain sequence to form a target binding structure (or “antigen binding site”), e.g., a structure that preferentially interacts with an activated integrin structure or a mimic of an activated integrin structure, e.g., relative to a non-activated structure.

The VH or VL chain of the antibody can further include all or part of a heavy
10 or light chain constant region, to thereby form a heavy or light immunoglobulin chain, respectively. In one embodiment, the antibody is a tetramer of two heavy immunoglobulin chains and two light immunoglobulin chains, wherein the heavy and light immunoglobulin chains are inter-connected by, e.g., disulfide bonds. The heavy chain constant region includes three domains, CH1, CH2 and CH3. The light chain
15 constant region includes a CL domain. The variable region of the heavy and light chains contains a binding domain that interacts with an antigen. The constant regions of the antibodies typically mediate the binding of the antibody to host tissues or factors, including various cells of the immune system (e.g., effector cells) and the first component (C1q) of the classical complement system. The term “antibody” includes
20 intact immunoglobulins of types IgA, IgG, IgE, IgD, IgM (as well as subtypes thereof). The light chains of the immunoglobulin may be of types kappa or lambda. In one embodiment, the antibody is glycosylated. An antibody can be functional or non-functional for antibody-dependent cytotoxicity and/or complement-mediated cytotoxicity.

25 One or more regions of an antibody can be human or effectively human. For example, one or more of the variable regions can be human or effectively human. For example, one or more of the CDRs can be human, e.g., HC CDR1, HC CDR2, HC CDR3, LC CDR1, LC CDR2, and LC CDR3. Each of the light chain CDRs can be human. HC CDR3 can be human. One or more of the framework regions can be
30 human, e.g., FR1, FR2, FR3, and FR4 of the HC or LC. In one embodiment, all the framework regions are human, e.g., derived from a human somatic cell, e.g., a hematopoietic cell that produces immunoglobulins or a non-hematopoietic cell. In one embodiment, the human sequences are germline sequences, e.g., encoded by a germline nucleic acid. One or more of the constant regions can be human or

effectively human. In another embodiment, at least 70, 75, 80, 85, 90, 92, 95, or 98% of, or the entire antibody can be human or effectively human. An “effectively human” immunoglobulin variable region is an immunoglobulin variable region that includes a sufficient number of human framework amino acid positions such that the immunoglobulin variable region does not elicit an immunogenic response in a normal human. An “effectively human” antibody is an antibody that includes a sufficient number of human amino acid positions such that the antibody does not elicit an immunogenic response in a normal human.

All or part of an antibody can be encoded by an immunoglobulin gene or a segment thereof. Exemplary human immunoglobulin genes include the kappa, lambda, alpha (IgA1 and IgA2), gamma (IgG1, IgG2, IgG3, IgG4), delta, epsilon and mu constant region genes, as well as the myriad immunoglobulin variable region genes. Full-length immunoglobulin “light chains” (about 25 Kd or 214 amino acids) are encoded by a variable region gene at the NH₂-terminus (about 110 amino acids) and a kappa or lambda constant region gene at the COOH--terminus. Full-length immunoglobulin “heavy chains” (about 50 Kd or 446 amino acids), are similarly encoded by a variable region gene (about 116 amino acids) and one of the other aforementioned constant region genes, e.g., gamma (encoding about 330 amino acids).

One exemplary method for identifying antibodies that bind to and inhibit kallikrein includes immunizing a non-human animal with kallikrein or a fragment thereof. Even small peptides can be used as immunogens. In one embodiment, a mutated kallikrein which has reduced or no catalytic activity is used as immunogen. Spleen cells can be isolated from the immunized animal and used to produce hybridoma cells using standard methods. In one embodiment, the non-human animal includes one or more human immunoglobulin genes.

Another exemplary method for identifying proteins that bind to and inhibit kallikrein includes: providing a library of proteins and selecting from the library one or more proteins that bind to a kallikrein or a fragment thereof. The selection can be performed in a number of ways. For example, the library can be provided in the format of a display library or a protein array. Prior to selecting, the library can be pre-screened (e.g., depleted) to remove members that interact with a non-target molecule, e.g., protease other than a kallikrein or a kallikrein in which the active site is inaccessible, e.g., bound by an inhibitor, e.g., aprotinin.

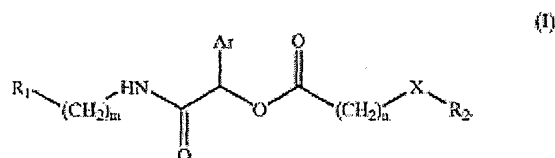
Antibody libraries, e.g., antibody display libraries, can be constructed by a number of processes (see, e.g., de Haard *et al.* (1999) *J. Biol. Chem* 274:18218-30; Hoogenboom *et al.* (1998) *Immunotechnology* 4:1-20. and Hoogenboom *et al.* (2000) *Immunol Today* 21:371-8). Further, elements of each process can be combined with those of other processes. The processes can be used such that variation is introduced into a single immunoglobulin domain (e.g., VH or VL) or into multiple immunoglobulin domains (e.g., VH and VL). The variation can be introduced into an immunoglobulin variable domain, e.g., in the region of one or more of CDR1, CDR2, CDR3, FR1, FR2, FR3, and FR4, referring to such regions of either and both of heavy and light chain variable domains. In one embodiment, variation is introduced into all three CDRs of a given variable domain. In another preferred embodiment, the variation is introduced into CDR1 and CDR2, e.g., of a heavy chain variable domain. Any combination is feasible. In an exemplary system for recombinant expression of an antibody (e.g., a full length antibody or an antigen-binding portion thereof), a recombinant expression vector encoding both the antibody heavy chain and the antibody light chain is introduced into *dhfr*- CHO cells by calcium phosphate-mediated transfection. Within the recombinant expression vector, the antibody heavy and light chain genes are each operatively linked to enhancer/promoter regulatory elements (e.g., derived from SV40, CMV, adenovirus and the like, such as a CMV enhancer/AdMLP promoter regulatory element or an SV40 enhancer/AdMLP promoter regulatory element) to drive high levels of transcription of the genes. The recombinant expression vector also carries a DHFR gene, which allows for selection of CHO cells that have been transfected with the vector using methotrexate selection/amplification. The selected transformant host cells are cultured to allow for expression of the antibody heavy and light chains and intact antibody is recovered from the culture medium. Standard molecular biology techniques are used to prepare the recombinant expression vector, transfect the host cells, select for transformants, culture the host cells, and recover the antibody from the culture medium. For example, some antibodies can be isolated by affinity chromatography with a Protein A or Protein G. Antibodies can also be produced by a transgenic animal.

Kallikrein Inhibitors- Small Molecules

An inhibitor of a kallikrein, e.g., plasma kallikrein, can also be a compound that is smaller than 3000, 2000 or 1000 Daltons. For example, the compound is a non-proteinaceous compound or a compound that includes fewer than five peptide
 5 bonds. Such small molecules can be used, e.g., to reduce or prevent reperfusion injury, e.g., reperfusion injury associated with cerebral ischemia, in a patient.

The inhibitor can be, e.g., a compound described in WO 04/062657, e.g., an acylated 4-amidino- or 4-guanidinobenzylamine. The compound can have the general formula (I) P4-P3-P2-P1 (I), where P4 is a mono- or poly-substituted or unsubstituted
 10 benzylsulphonyl group, P3 is a mono- or poly-substituted or unsubstituted, natural or unnatural alpha-amino or alpha-imino acid with the D-configuration, P2 is a mono- or poly-substituted or unsubstituted natural or unnatural alpha-amino or alpha-imino acid with the L-configuration and P1 is a mono- or poly-substituted or unsubstituted 4-amidino- or 4-guanidinobenzylamine group.

15 Another example is a compound represented by Structural Formula (I):



R1 is a substituted or unsubstituted aryl group or alkyl group; R2 is a substituted or unsubstituted aryl group or cycloalkyl group; Ar is a substituted or unsubstituted aryl group; X is a -CH2-, -O-, -S- or -CO-; m is an integer from zero to
 20 two; n is an integer from 0-2 when X is -O-, -S- and 1-2 when X is -CH2- or -CO-. Exemplary compounds are described in US 2004-044075.

Anti-Thrombolytic Agents

Anti-thrombolytic agents are agents that reduce or prevent dissolution of a
 25 blood clot, stabilize a blood clot, increase clotting and/or prevent abnormal amounts of blood loss such as hemorrhaging by maintaining, stabilizing or increasing a blood clot. Preferably, the anti-thrombolytic agent is an anti-fibrinolytic agent. Anti-fibrinolytic agents are agents that prevent or reduce the dissolution or breakdown of fibrin. Examples of anti-fibrinolytic agents include tranexamic acid (CyklokapronTM),
 30 epsilon amino caproic acid (AmicarTM), aprotinin (TrasyolTM), Desmopressin

(DDAVP), pirfenidone, and combinations thereof. The anti-fibrinolytic activity of an agent may be determined by any *in vitro* clot lysis activity known in the art, such as the purified clot lysis assay described by Carlson, *et al.*, *Anal. Biochem.* 168, 428-435 (1988) and its modified form described by Bennett, W. F. *et al.*, 1991, *supra*, the
5 entire contents of which are hereby incorporated by reference.

Methods and Compositions

The kallikrein inhibitors and the anti-thrombolytic agents described herein can be used in methods for preventing or reducing blood loss, e.g., perioperative blood
10 loss; methods for preventing or reducing injury associated with ischemia (e.g., reperfusion injury associated with ischemia); and/or a systemic inflammatory response (SIR) in a patient, especially associated with surgery. The surgery can be, e.g., a cardiothoracic surgery, (e.g., cardiopulmonary bypass or coronary artery bypass grafting); orthopedic surgery (e.g., hip or knee replacement or bone fracture);
15 liver surgery; kidney surgery; procedures that utilize extracorporeal circulation or dialysis; and any other procedure which can result in perioperative blood loss. The method includes administering a non-naturally occurring inhibitor of kallikrein, e.g., plasma kallikrein, in combination with an anti-thrombolytic agent, e.g., an anti-fibrinolytic agent.

20 In one embodiment, a method for treatment includes administration of a non-naturally occurring polypeptide comprising a Kunitz domain as the inhibitor of kallikrein. One embodiment of the method uses a polypeptide containing an amino acid sequence of SEQ ID NO:1 that has an affinity for kallikrein that is approximately 30-fold or more higher than that of a broad range serine protease, e.g., aprotinin,
25 which is isolated from bovine lung and currently approved for use in CABG procedures (TRASYLOL™, Bayer Corporation Pharmaceutical Division, West Haven, Conn.).

Patients subjected to any of a number of surgical procedures, especially those involving extra-corporeal circulation, e.g., cardiothoracic surgery, such as, for
30 example, CPB, and/or bone trauma, such as sternal split or hip replacement, are at risk for perioperative blood loss and inflammation. Contact of a patient's blood with the cut surfaces of bone or of CPB equipment is sufficient to activate one or several undesirable cascade responses, including a contact activation system (CAS), which

can lead to extensive perioperative blood loss requiring immediate blood transfusion, as well as a systemic inflammatory response (SIR), which, in turn, can result in permanent damage to tissues and organs. While not desiring to be limited to any particular mechanism or theory, it appears that the blood loss that occurs associated
5 with cardiothoracic surgery, e.g., CPB, as in a CABG procedure, probably results from extensive capillary leakage, which can result in significant loss of blood that must be replaced by immediate blood transfusion.

The combination treatment described herein can be used to prevent or reduce perioperative blood loss as well as various ischemias and SIR in a patient subjected to
10 a surgical procedure, and especially wherein the surgical procedure requires extra-corporeal circulation, e.g., cardiothoracic surgery, such as, for example, CPB. The combination treatment can be particularly useful for preventing or reducing perioperative blood loss and/or SIR in a patient subjected to a CABG procedure requiring CPB or other cardiac surgery.

15 The treatment described herein can be used to prevent or reduce cerebral ischemia (such as stroke) and/or reperfusion injury associated with cerebral ischemia (e.g., stroke), e.g., a kallikrein inhibitor can be administered either alone or in combination with an anti-thrombolytic agent, to prevent or reduce cerebral ischemia and/or reperfusion injury associated with ischemia.

20 Exemplary compositions for medical use comprise a kallikrein inhibitor described herein, an anti-thrombolytic agent described herein or both a kallikrein inhibitor described herein and an anti-thrombolytic agent described herein. Such compositions can further include one or more pharmaceutically acceptable buffers, carriers, and excipients, which can provide a desirable feature to the composition
25 including, but not limited to, enhanced administration of the composition to a patient, enhanced circulating half-life of the inhibitor and/or anti-thrombolytic agent, enhanced compatibility of the inhibitor and/or anti-thrombolytic agent with patient blood chemistry, enhanced storage of the composition, and/or enhanced delivery and/or efficacy of the inhibitor and/or anti-thrombolytic agent upon administration to
30 a patient. In addition to a kallikrein inhibitor and/or anti-thrombolytic agent described herein, compositions can further include one or more other pharmaceutically active compounds that provide an additional prophylactic or therapeutic benefit to a patient, e.g., a patient of an invasive surgical procedure or a patient otherwise at risk for, having or previously had cerebral ischemia and/or reperfusion injury associated with

cerebral ischemia. For example, the compositions can include another compound described herein.

Perioperative Blood Loss and Reduced Heart Bloodflow

5 Due to the many advances in medicine, a number of highly invasive surgical procedures are carried out each day that result in blood loss, or place patients at a high risk for blood loss. Such patients are generally carefully monitored to restore and maintain normal blood supply and hemostasis, and they may need blood transfusions. Surgical procedures that involve blood loss include those involving extra-corporeal
10 circulation methods such as cardiothoracic surgery, e.g., CPB. In such methods, a patient's heart is stopped and the circulation, oxygenation, and maintenance of blood volume are carried out artificially using an extra-corporeal circuit and a synthetic membrane oxygenator. These techniques are commonly used during cardiac surgery. Additionally, it is apparent that surgery involving extensive trauma to bone, such as
15 the sternal split necessary in CABG or hip replacement procedures, is also associated with activation of the CAS, which can result in a variety of disruptions in the blood and vasculature.

 Atherosclerotic coronary artery disease (CAD) causes a narrowing of the lumen of one or several of the coronary arteries; this limits the flow of blood to the
20 myocardium (i.e., the heart muscle) and can cause angina, heart failure, and myocardial infarcts. In the end stage of coronary artery atherosclerosis, the coronary circulation can be almost completely occluded, causing life threatening angina or heart failure, with a very high mortality. CABG procedures may be required to bridge the occluded blood vessel and restore blood to the heart; these are potentially life
25 saving. CABG procedures are among the most invasive of surgeries in which one or more healthy veins or arteries are implanted to provide a "bypass" around the occluded area of the diseased vessel. CABG procedures carry with them a small but important perioperative risk, but they are very successful in providing patients with immediate relief from the mortality and morbidity of atherosclerotic cardiovascular
30 disease. Despite these very encouraging results, repeat CABG procedures are frequently necessary, as indicated by an increase in the number of patients who eventually undergo second and even third procedures; the perioperative mortality and morbidity seen in primary CABG procedures is increased in these re-do procedures.

There have been improvements in minimally invasive surgical techniques for uncomplicated CAD. However, nearly all CABG procedures performed for valvular and/or congenital heart disease, heart transplantation, and major aortic procedures, are still carried out on patients supported by CPB. In CPB, large cannulae are inserted
5 into the great vessels of a patient to permit mechanical pumping and oxygenation of the blood using a membrane oxygenator. The blood is returned to the patient without flowing through the lungs, which are hypoperfused during this procedure. The heart is stopped using a cardioplegic solution, the patient cooled to help prevent brain damage, and the peripheral circulating volume increased by an extracorporeal circuit,
10 i.e., the CPB circuit, which requires "priming" with donor blood and saline mixtures are used to fill the extracorporeal circuit. CPB has been extensively used in a variety of procedures performed for nearly half a century with successful outcomes. The interaction between artificial surfaces, blood cells, blood proteins, damaged vascular endothelium, and extravascular tissues, such as bone, disturbs hemostasis and
15 frequently activates the CAS, which, as noted above, can result in a variety of disruptions in the blood and vasculature. Such disruption leads to excess perioperative bleeding, which then requires immediate blood transfusion. A consequence of circulating whole blood through an extracorporeal circuit in CPB can also include the systemic inflammatory response (SIR), which is initiated by contact
20 activation of the coagulation and complement systems. Indeed, much of the morbidity and mortality associated with seemingly mechanically successful CPB surgical procedures is the result of the effects of activating coagulation, fibrinolysis, or complement systems. Such activation can damage the pulmonary system, leading to adult respiratory distress syndrome (ARDS), impairment of kidney and splanchnic
25 circulation, and induction of a general coagulopathy leading to blood loss and the need for transfusions. In addition to the dangers of perioperative blood loss, additional pathologies associated with SIR include neurocognitive deficits, stroke, renal failure, acute myocardial infarct, and cardiac tissue damage.

Blood transfusions also present a significant risk of infection and elevate the
30 cost of CABG or other similar procedures that require CPB. In the absence of any pharmacological intervention, three to seven units of blood must typically be expended on a patient, even with excellent surgical techniques. Accordingly, there is considerable incentive for the development of new and improved pharmacologically effective compounds and treatment protocols to reduce or prevent perioperative

bleeding and SIR in patients subjected to CPB and CABG procedures. Use of the inhibitors described herein in combination with various anti-thrombolytic agents (e.g., anti-fibrinolytic agents) can improve these various treatments and lead to reduction and/or amelioration of the undesirable symptoms that can occur.

5

Cerebral Ischemia and Reperfusion Injury

The methods described herein are useful for reducing or preventing cerebral ischemia as well as reperfusion injury associated with cerebral ischemia. A “cerebral ischemic attack” or “cerebral ischemia” is an ischemic condition in which blood
10 supply to the brain is blocked. This interruption in the blood supply to the brain may result from a variety of causes including, but not limited to, an intrinsic blockage or occlusion of the blood vessel itself, a remotely originated source of occlusion, decreased perfusion pressure or increased blood viscosity resulting in decreased cerebral blood flow, or ruptured or leaky blood vessels in the subarachnoid space or
15 intracerebral tissue. Cerebral ischemia may result in either transient or permanent deficits and the seriousness of the neurological damage in a patient who has experienced cerebral ischemia depends on the intensity and duration of the ischemia event. A transient ischemia attack (TIA) is one in which the blood flow to the brain is briefly interrupted and causes temporary neurological deficits. Symptoms of TIA
20 include numbness or weakness of face or limbs, loss of ability to speak clearly and/or understand the speech of others, a loss of vision or dimness of vision and dizziness. Permanent cerebral ischemia attacks, also called strokes, are caused by a longer interruption in blood flow to the brain resulting from an embolism, a thrombus or bleeding in the brain (e.g., a hemorrhage). The term “thromboembolic stroke” or
25 “thromboembolism” is used herein to refer to a stroke caused by either a thrombosis or an embolism. A stroke causes a loss of neurons typically resulting in a neurological deficit that may improve but does not entirely resolve. The treatments described herein including the combination treatments are useful in preventing or reducing stroke including embolic-, thrombotic-, thromboembolic- and hemorrhage-
30 associated strokes. Strokes can be caused by a variety of causes. One category includes perioperative strokes that can be associated with thrombus or embolism formation.

In stroke patients, there is a core of the neurological deficit marked by total ischemia and/or tissue necrosis. This area is normally surrounded by ischemic tissue,

referred to as the ischemic penumbra, that receives collateral circulation. Ischemia in the penumbra does not always result in irreversible damage. In some cases, restoration of blood flow (reperfusion) into the penumbra may prevent total ischemia and necrosis in this area. However, reperfusion has also been associated with injury to the tissue surrounding the core. Once blood flow is returned, blood cells such as neutrophils, attack the damaged tissue which can cause additional inflammation and/or damage. Reperfusion injury is associated with an influx of neutrophils into the affected tissue and subsequent activation of the neutrophils. Neutrophils can release lytic enzymes that directly induce tissue damage and proinflammatory mediators such as cytokines that amplify local inflammatory reaction. The influx of neutrophils to a site of ischemic damage can also plug capillaries and cause vasoconstriction. It has been found that kallikrein plays a role in neutrophil chemotaxis, neutrophil activation and reperfusion injury. Thus, the kallikrein inhibitors described herein can be used to prevent or reduce reperfusion injury, e.g., by reducing or preventing one or more of:

- 1) neutrophil infiltration; 2) neutrophil activation; 3) cytokine release; 4) elastase release; and 5) vasodilation. For example, a kallikrein inhibitor can be used to inhibit bradykinin and Factor XII. The kallikrein inhibitors can be used in combination with one or more anti-thrombolytic agent, e.g., one or more anti-thrombolytic agent described herein.

20

Administration

A kallikrein inhibitor and/or anti-thrombolytic agent can be administered to a patient before, during, and/or after an event that causes or is associated with blood loss, e.g., a surgical procedure, or an ischemic event, e.g., a cerebral ischemic attack, in a pharmaceutically acceptable composition or in connection with another disorder or event described herein. The patient is generally a human, but may also be a non-human mammal. Human patients include adults, e.g., patients between ages 19-25, 26-40, 41-55, 56-75, and 76 and older, and pediatric patients, e.g., patients between ages 0-2, 3-6, 7-12, and 13-18.

The term "pharmaceutically acceptable" composition refers to a non-toxic carrier or excipient that may be administered to a patient, together with a kallikrein inhibitor and/or anti-thrombolytic agent described herein. The carrier or excipient is chosen to be compatible with the biological or pharmacological activity of the

composition. The inhibitors and/or anti-thrombolytic agents described herein can be administered locally or systemically by any suitable means for delivery of an inhibitory amount of the inhibitor and/or anti-thrombolytic agent to a patient including but not limited to systemic administrations such as, for example,
5 intravenous and inhalation. Parenteral administration is particularly preferred.

For parenteral administration, the kallikrein inhibitor and/or the anti-thrombolytic agent can be injected intravenously, intramuscularly, intraperitoneally, or subcutaneously. Intravenous administration is preferred. Typically, compositions for intravenous administration are solutions in sterile isotonic aqueous buffer. Other
10 pharmaceutically acceptable carriers include, but are not limited to, sterile water, saline solution, and buffered saline (including buffers like phosphate or acetate), alcohol, vegetable oils, polyethylene glycols, gelatin, lactose, amylose, magnesium stearate, talc, silicic acid, paraffin, etc. Where necessary, the composition can also include a solubilizing agent and a local anaesthetic such as lidocaine to ease pain at
15 the site of the injection, preservatives, stabilizers, wetting agents, emulsifiers, salts, lubricants, etc. as long as they do not react deleteriously with the active compounds. Similarly, the composition can comprise conventional excipients, e.g., pharmaceutically acceptable organic or inorganic carrier substances suitable for parenteral, enteral or intranasal application which do not deleteriously react with the
20 active compounds. Generally, the ingredients will be supplied either separately or mixed together in unit dosage form, for example, as a dry lyophilized powder or water free concentrate in a hermetically sealed container such as an ampoule or sachette indicating the quantity of active agent in activity units. Where the composition is to be administered by infusion, it can be dispensed with an infusion bottle containing
25 sterile pharmaceutical grade "water for injection" or saline. Where the composition is to be administered by injection, an ampoule of sterile water for injection or saline can be provided so that the ingredients can be mixed prior to administration.

In one embodiment, the kallikrein inhibitor and/or anti-thrombolytic agent is administered to a patient as an intravenous infusion according to any approved
30 procedure. For example, a non-naturally occurring kallikrein inhibitor described herein and an anti-thrombolytic agent (e.g., an anti-fibrinolytic agent) can be administered to a patient subjected to a CABG procedure at the times similar to those currently used in approved protocols for administering aprotinin and in an amount necessary to provide a patient with a required number or concentration of kallikrein

inhibitory units (KIU). In another embodiment, each of the non-naturally occurring kallikrein inhibitor and the anti-thrombolytic agent, e.g., anti-fibrinolytic agent, is administered in an amount necessary to provide a patient with a required number or concentration of kallikrein inhibitory units (KIU).

5 A kallikrein inhibitor and/or anti-thrombolytic agent described herein can also be administered to a patient in the immediate postoperative period, when bleeding abnormalities can occur as a consequence of downstream effects of SIR. For example, in a procedure involving CPB, an inhibitor and/or anti-thrombolytic agent described herein can be administered to a patient as an initial loading dose, e.g., an
10 effective amount over the course of a convenient time, such as 10 minutes, prior to induction of anesthesia. Then, at induction of anesthesia, a second dose of the inhibitor and/or anti-thrombolytic agent can be injected into the CPB priming fluid ("pump prime volume"). The patient can then be placed on a continuous and controlled intravenous infusion dose for the duration of the surgical procedure, and
15 after the procedure if indicated.

 In other embodiments, a kallikrein inhibitor and/or anti-thrombolytic agent can be administered after an ischemic event, e.g., after a stroke, e.g., 5, 10, 15, 30, 45 minutes, 1, 2, 3, 5, 10, 15, 20 hours or more after a stroke. Preferably, the inhibitor and/or anti-thrombolytic agent is administered within 12 to 60 hours, e.g., within 24
20 to 48 hours, after a stroke. In some embodiments, a kallikrein inhibitor and/or anti-thrombolytic agent is administered after an ischemic event, e.g., after a stroke, but prior to reperfusion of the damaged tissue. In other embodiments, a kallikrein inhibitor and/or anti-thrombolytic agent is administered during reperfusion or after reperfusion has begun. In yet another embodiment, a kallikrein inhibitor and/or anti-
25 thrombolytic agent is administered after reperfusion has occurred. An "effective" amount in this context is an amount sufficient to reduce one or more symptoms associated with cerebral ischemia and/or reperfusion injury associated with cerebral ischemia which otherwise would have occurred in a subject experiencing a cerebral ischemia and/or reperfusion injury associated with cerebral ischemia absent the
30 treatment. Several physiological parameters may be used to assess stroke and reperfusion injury associated with stroke including infarct size, regional cerebral blood flow, intracranial pressure, anterograde amnesia, retrograde amnesia, dementia, cognitive function and/or emotion, and cerebral edema, for example, as compared to pretreatment patient parameters, untreated stroke patients or stroke patients treated

with the other therapeutic agent but not the combination with the inhibitor (e.g., the Kunitz domain polypeptide or other compound described herein) or visa versa.

Parameters that can be evaluated for determining a dose of the kallikrein inhibitor, the anti-thrombolytic agent, or both are described below with regards to

5 DX-88 (a non-naturally occurring kallikrein inhibitor) and aprotinin (an anti-fibrinolytic agent). By determining information regarding, for example, the KIU and binding specificity, an appropriate dose of each of the kallikrein inhibitor and the anti-thrombolytic agent can be determined for the desired therapeutic or prophylactic effect.

10 With respect to an implementation in which DX-88 or a DX-88-related inhibitor is used, the affinity constant (K_i) of DX-88 is at least about 1000 times greater than aprotinin for kallikrein inhibition. Accordingly, a dose of DX-88 or an inhibitor of similar affinity can be, e.g., at least about 5, 10, 15, 20, 30, 50, 100, 500 or 1000 times lower than aprotinin on a mole per mole basis. The dose could also be
15 modulated as a function of the amount of kallikrein activated during an event (e.g., CPB), the specificity of the DX-88-kallikrein interaction in vivo, the concentration of kallikrein eliciting SIRS, and pharmacological distribution. In one aspect, the dose of DX-88 or an inhibitor of similar affinity administered in combination with an anti-fibrinolytic agent such as aprotinin can be adjusted such that the KIU for the
20 combination is the same as it would be if only DX-88 or only aprotinin were administered. In other embodiments, each of DX-88 (or an inhibitor of similar affinity) and the anti-fibrinolytic agent, e.g., aprotinin, is administered at a dose the same or similar to that given in the absence of the other agent. Similar adjustments can be made for other anti-thrombolytic agents, e.g., anti-fibrinolytic agents,
25 described herein.

The total amount of circulating prekallikrein in plasma is reported to be approximately 500 nM to 600 nM. Silverberg, M. et al., "The Contact System and Its Disorders," in Blood: Principles and Practice of Hematology, Handin, R. et al., eds, J B Lippincott Co., Philadelphia, 1995). If all prekallikrein is activated, about 520
30 nmoles/L of DX-88 can be used to inhibit kallikrein in a stoichiometric manner. An individual having 5 L of plasma would require a dose of 2.6 micromoles DX-88, or approximately 18 mg based on the molecular weight of DX-88 of 7,054 Daltons. This was calculated as follows: the K_i of DX88 is 0.044 nM. When it is desired to have a concentration of plasma kallikrein (PK) of, e.g., 1nM, the formula $K_i = 0.044nM$

= $[DX88] \times [PK]/[DX88-PK] = [DX88] \times 1 \text{ nm}/499 \text{ nM}$, indicates that the concentration of free DX-88 is 22.0 nM. Thus, the total amount of DX-88 needed would be 499 + 22 or 521 nM. The dose can be reduced proportionally if not all of the prekallikrein is activated or if a portion of the kallikrein is deactivated by an endogenous inhibitor, e.g., C1 esterase inhibitor (C1INH). Thus, in certain embodiments, about 5, 10, 15, 20, 30, 40, 60, 80, 120, 250, 500, 600, 700, 800, 1000 mg of DX-88 can be administered to a subject, e.g., over a twenty-four hour period. In other embodiments, less than 5, 10, 15, 20, 30, 40, 60, 80, 120, 250, 500, 600, 700, 80, 1000 mg of DX-88 can be administered, e.g., over a twenty-four hour period, such that the combination of DX-88 with an anti-thrombolytic agent has a similar (or better) effect on one or more symptom of the disorder than if DX-88 were administered alone.

As the concentration of active kallikrein may have to rise above a certain level to contribute to increased fluid and blood loss post-operatively, in many cases, it is not necessary to inactivate all active kallikrein. DX-88 would be expected to be effective at a significantly lower dose compared to aprotinin on the basis of its higher affinity for kallikrein. Using the same calculations described above, if all prekallikrein is activated, about 15,469 nmoles/L of aprotinin can be used to inhibit kallikrein in a stoichiometric manner. Therefore, an individual having 5 L of plasma would require a dose of 77.5 micromoles aprotinin, or approximately 542 mg.

DX-88 also has greater specificity for kallikrein inhibition compared to aprotinin in vitro. Therefore, proteases other than kallikrein that are inhibited by aprotinin may lower the effective concentration of the inhibitor, thereby increasing the amount of aprotinin needed for a therapeutic effect and leading to unwanted side effects.

Currently there are two regimens approved in the United States for administering aprotinin to a patient undergoing a CABG procedure (see, product label and insert for TRASYLOL™, Bayer Corporation Pharmaceutical Division, West Haven, Conn., the contents of which are incorporated herein).

Several considerations regarding dosing with a polypeptide inhibitor of kallikrein can be illustrated by way of example with the representative DX-88 polypeptide.

Table 1, below, provides a comparison of the affinity ($K_{i,app}$) of the DX-88 polypeptide for kallikrein and eleven other known plasma proteases.

TABLE 1:

Protease Substrate	DX-88 $K_{i,app}$ (pM)	Aprotinin $K_{i,app}$ (pM)
human plasma kallikrein	44	3.0×10^4
human urine kallikrein	$>1 \times 10^8$	4.0×10^3
porcine pancreatic kallikrein	2.7×10^7	550
human C1r, activated	$>2.0 \times 10^8$	$>1.0 \times 10^7$
human C1s, activated	$>2.0 \times 10^7$	$>1.0 \times 10^8$
human plasma factor XIa	1.0×10^4	ND
human plasma factor XIIa	$>2.0 \times 10^7$	$>1.0 \times 10^8$
human plasmin	1.4×10^5	894
human pancreatic trypsin	$>2 \times 10^7$	ND
human pancreatic chymotrypsin	$>2.0 \times 10^7$	7.3×10^5
human neutrophil elastase	$>2.0 \times 10^7$	1.7×10^6
human plasma thrombin	$>2.0 \times 10^7$	$>1.0 \times 10^8$

ND = not determined

5 Clearly, the DX-88 polypeptide is highly specific for human plasma kallikrein. Furthermore, the affinity ($K_{i,app}$) of DX-88 for kallikrein is 700 times higher than the affinity of aprotinin for kallikrein: the $K_{i,app}$ of DX-88 for kallikrein is about 44 pM (Table 1), whereas the $K_{i,app}$ of aprotinin for kallikrein is 30,000 pM. Thus, a dose of DX-88 could be lower than that used for aprotinin on a per mole basis. Using this
10 information, the dose of each of DX-88 and aprotinin can be determined.

 Consideration of several other factors may provide a more accurate estimation of the dose of DX-88 required in practice. Such factors include the amount of kallikrein activated during CPB in a particular patient, the concentration of kallikrein required to elicit an SIR, the bioavailability and pharmacological distribution of DX-
15 88 in a patient and the effect of C1 esterase inhibitor on endogenous plasma kallikrein inhibition. Nevertheless, use of a polypeptide that includes a Kunitz domain that inhibits kallikrein in doses currently approved for the use of aprotinin is still expected to provide significant improvements over the current use of the less specific, lower affinity, bovine aprotinin. Accordingly, lower doses, e.g., at least half, or a tenth of

the approved aprotinin dose may be used for a kallikrein inhibitor which inhibits kallikrein at least 2, 5, 10, 20, 30, 50 or 100 fold better than aprotinin.

Another factor to consider is the threshold concentration of kallikrein required to induce a SIR in a patient. If the concentration of active kallikrein must be
5 maintained below, e.g., 1 nM, then owing to its high affinity for kallikrein, DX-88 offers a significant advantage over aprotinin in the amount of protein that would be required to inhibit SIR.

In some embodiment, the kallikrein inhibitor polypeptide is administered in a dose of about 1-500 mg/m², preferably about 1-250 mg/m², 1-100 mg/m². For
10 example, a kallikrein inhibitor polypeptide, e.g., a kallikrein inhibitor polypeptide described herein, can be administered to a subject at risk for cerebral ischemia, suffering from cerebral ischemia, or who has suffered a cerebral ischemic attack at a dose of 1-100 mg/m². In other embodiments, the dose of the kallikrein inhibitor polypeptide can be less than the doses provided above. For example, the dose of the
15 kallikrein inhibitor can be reduced, such that the combination of the kallikrein inhibitor polypeptide and the anti-thrombolytic agent, give the same or a similar effect as the kallikrein inhibitor polypeptide given at a higher dose.

Suggested dosage regimens for other anti-thrombolytic agents, e.g., anti-fibrinolytic agents, are known. In some embodiments, the suggested dose of the anti-
20 thrombolytic agent, e.g., anti-fibrinolytic agent, can be adjusted such that the combination treatment has, e.g., the same (or better) therapeutic effect than the anti-thrombolytic agent, e.g., anti-fibrinolytic agent given at its suggested dose. Current dosing regimens for epsilon amino caproic acid (AmicarTM) are as follows: in adult patients, epsilon amino caproic acid is administered is given at 4 to 5 grams in the
25 first hour and then at 1-1.25 grams/hour, three to four times a day. The current dosing regimen for tranexamic acid (CyklokapronTM) is 10 mg/kg every 6-8 hours for 7 to 10 days.

The kallikrein inhibitor can be administered before, concurrently with, or after
30 the administration of the anti-thrombolytic agent.

The methods described herein can further include administration of another agent or agents other than the kallikrein inhibitor and the anti-thrombolytic agent. For example, an anti-coagulation agent or anti-platelet agent can also be administered to the patient.

Anticoagulation agents prevent the coagulation of blood components and thus prevent clot formation. Anticoagulants include, but are not limited to, heparin, warfarin, coumadin, dicumarol, phenprocoumon, acenocoumarol, ethyl biscoumacetate, hirudin, bivalarutin, and other direct thrombin inhibitors, and
5 indandione derivatives.

Anti-platelet agents inhibit platelet aggregation and are often used to prevent thromboembolic stroke in patients who have experienced a transient ischemic attack or stroke. Anti-platelet agents include, but are not limited to, aspirin, thienopyridine derivatives such as ticlopodine and clopidogrel, dipyridamole and sulfinpyrazone, as
10 well as RGD mimetics.

The kallikrein inhibitor polypeptides are non-naturally occurring, and can be, e.g., produced synthetically or recombinantly, as noted above, thereby avoiding
15 potential contamination of transmissible diseases that can arise during isolation of a protein from a natural animal source, such as in the case of aprotinin, which is isolated from bovine lung. Increasingly important to administrative and public acceptance of a treatment or pharmaceutical composition comprising a polypeptide is the avoidance of possible contamination with and transmission to human patients of
20 various pathological agents. Of particular interest for the safety of proteins isolated from a bovine tissue is the elimination of the possible risk of exposure to viral mediated diseases, bacterial mediated diseases, and, especially, transmissible bovine spongiform encephalopathies.

As variants of the Kunitz domain 1 of the human LACI protein, fewer side
25 effects are expected from administering the kallikrein inhibitor polypeptides to patients than for aprotinin, which is a bovine protein that is documented to cause anaphylactic and anaphylactoid responses in patients, especially in repeat administrations, such as second time CABG procedures. Additionally, the highly specific binding of the kallikrein inhibitor polypeptides described herein to kallikrein
30 can limit or eliminate the thrombotic tendencies observed with aprotinin, and/or reduce the problems observed with graft patency following CABG procedures.

In some embodiments, the kallikrein inhibitor polypeptide is administered in combination with aprotinin, and one or more side effect associated with aprotinin is reduced or eliminated. One or more side effect of aprotinin that can be reduced or

prevented by a combination treatment with a non-naturally occurring kallikrein inhibitor include, but are not limited to: hypersensitivity and pseudo-allergic reactions; itching; rash; sweating; urticaria; skin eruptions; pallor or cyanosis; dyspnoea; nausea; drop in blood pressure; tachycardia or bradycardia; airway
5 obstruction; severe hypotension and anaphylactic shock; renal dysfunction; kidney failure; increase risk of graft closure; increased risk of myocardial infarction.

In other embodiments, the kallikrein inhibitor polypeptide is administered in combination with one or more of epsilon amino caproic acid and/or tranexamic acid and, e.g., one or more side effect associated with administration epsilon amino caproic
10 acid and/or tranexamic acid is reduced or eliminated. One or more side effect of epsilon amino caproic acid and/or tranexamic acid that can be reduced or prevented by a combination treatment with a non-naturally occurring kallikrein inhibitor include, but are not limited to: blood clots; headache; loss of coordination; pains in chest, groin, or legs, especially the calves; shortness of breath; slurred speech; vision
15 changes; weakness or numbness in arm or leg; ringing or buzzing in ears; skin rash; slow or irregular heart beat; stomach cramps; swelling of face, feet or lower legs; unusual tiredness; weight gain; decrease in amount of urine in patient; diarrhea, nausea or vomiting; seizures; and hallucination.

20 Devices and Kits

Pharmaceutical compositions that include the kallikrein inhibitor and/or the anti-thrombolytic agent (e.g., the anti-fibrinolytic agent) can be administered with a medical device. The device can designed with features such as portability, room temperature storage, and ease of use so that it can be used in emergency situations,
25 e.g., by an untrained subject or by emergency personnel in the field, removed to medical facilities and other medical equipment. The device can include, e.g., one or more housings for storing pharmaceutical preparations that include a non-naturally occurring kallikrein inhibitor and/or an anti-thrombolytic agent, and can be configured to deliver one or more unit doses of the agent or agents.

30 For example, the pharmaceutical composition can be administered with a device disclosed in US 4,447,233, which discloses a medication infusion pump for delivering medication at a precise infusion rate; and US 4,447,224, which discloses a

variable flow implantable infusion apparatus for continuous drug delivery. Many other devices, implants, delivery systems, and modules are also known.

A non-naturally occurring kallikrein inhibitor and/or anti-thrombolytic agent can be provided in a kit. In one embodiment, the kit includes (a) a container that
5 contains a composition that includes a non-naturally occurring kallikrein inhibitor, and optionally (b) informational material. The informational material can be descriptive, instructional, marketing or other material that relates to the methods described herein and/or the use of the agents for therapeutic benefit. In an
10 embodiment, the kit includes also includes an anti-thrombolytic agent. For example, the kit includes a first container that contains a composition that includes the non-naturally occurring kallikrein inhibitor, and a second container that includes the anti-thrombolytic agent.

The informational material of the kits is not limited in its form. In one embodiment, the informational material can include information about production of
15 the compound, molecular weight of the compound, concentration, date of expiration, batch or production site information, and so forth. In one embodiment, the informational material relates to methods of administering the non-naturally occurring kallikrein inhibitor, e.g., in a suitable dose, dosage form, or mode of administration (e.g., a dose, dosage form, or mode of administration described herein), to treat a
20 subject who has or is at risk for blood loss, injury associated with ischemia (e.g., ischemia associated with perioperative blood loss, cerebral ischemia, reperfusion injury, e.g., reperfusion injury associated with cerebral ischemia or a focal brain ischemia), and/or the onset of systemic inflammatory response, e.g., in patients subjected to invasive surgical procedures, especially procedures requiring
25 cardiopulmonary bypass. In one embodiment, the instructions provide a dosing regimen, dosing schedule, and/or route of administration of the kallikrein inhibitor that differs from the dosing regimen, dosing schedule and/or route of administration for the kallikrein inhibitor in the absence of the anti-thrombolytic agent, e.g., a dosing regimen described herein. The information can be provided in a variety of formats,
30 include printed text, computer readable material, video recording, or audio recording, or a information that provides a link or address to substantive material.

In addition to the non-naturally occurring kallikrein inhibitor and/or anti-thrombolytic agent, the composition in the kit can include other ingredients, such as a solvent or buffer, a stabilizer, or a preservative. The non-naturally occurring

kallikrein inhibitor and/or anti-thrombolytic agent can be provided in any form, e.g., liquid, dried or lyophilized form, preferably substantially pure and/or sterile. When the agents are provided in a liquid solution, the liquid solution preferably is an aqueous solution. When the agents are provided as a dried form, reconstitution
5 generally is by the addition of a suitable solvent. The solvent, e.g., sterile water or buffer, can optionally be provided in the kit.

The kit can include one or more containers for the composition or compositions containing the agents. In some embodiments, the kit contains separate containers, dividers or compartments for the composition and informational material.
10 For example, the composition can be contained in a bottle, vial, or syringe, and the informational material can be contained in a plastic sleeve or packet. In other embodiments, the separate elements of the kit are contained within a single, undivided container. For example, the composition is contained in a bottle, vial or syringe that has attached thereto the informational material in the form of a label. In some
15 embodiments, the kit includes a plurality (e.g., a pack) of individual containers, each containing one or more unit dosage forms (e.g., a dosage form described herein) of the agents. The containers can include a combination unit dosage, e.g., a unit that includes both the non-naturally occurring kallikrein inhibitor and the anti-thrombolytic agent, e.g., in a desired ratio. For example, the kit includes a plurality of
20 syringes, ampules, foil packets, blister packs, or medical devices, e.g., each containing a single combination unit dose. The containers of the kits can be air tight, waterproof (e.g., impermeable to changes in moisture or evaporation), and/or light-tight.

The kit optionally includes a device suitable for administration of the composition, e.g., a syringe or other suitable delivery device. The device can be
25 provided pre-loaded with one or both of the agents or can be empty, but suitable for loading.

EXAMPLES:

Example 1: Neuroprotective effect of kallikrein inhibitor polypeptide at various doses
30 on brain ischemia/reperfusion injury.

The presence of tissue kallikrein in the brain and the identification of bradykinin B2 receptors on brain cells suggest that kinin system could play a role in the nervous system pathophysiology. Recent data showing the effectiveness of

bradykinin B2 receptor antagonists in reducing ischemic brain damage further supports such a hypothesis.

In this example, a kallikrein inhibitor polypeptide (DX-88) is effective in reducing neurological deficits and brain injury after transient focal brain ischemia.

5 In vitro analysis was performed to determine whether DX-88 was able to cross the blood-brain barrier. Non-ischemic mice were treated iv with saline or DX-88 (10 µg/mouse or 30 µg/mouse) and plasma was drawn 30 or 60 min after administration. Thirty minutes after DX-88 treatment, plasma kallikrein inhibitory activity was 2 and 4 times higher in mice treated with 30 and 10 µg, respectively.
10 Such a difference was not seen in plasma drawn 60 min after the infusion. In cerebral spinal fluid (CSF) from mice treated with 30 µg of DX-88, there was marked inhibitory activity with no difference between CSF drawn 30 or 60 min after DX-88 administration.

Ischemia was induced by occlusion of the middle cerebral artery (MCAO). At
15 the end of the ischemic period (30 min), the filament was removed and reperfusion allowed. Mice received different doses of DX-88 iv at the beginning of the ischemic period. Twenty four hours after ischemia, neurological deficits and infarct size were evaluated. While saline treated mice showed stable scores, those who received 30 mg of DX-88 had significantly reduced general (13 and 10.5, median of saline and DX-88
20 treated mice, respectively) and focal (26 and 15.5, median of saline and DX-88 treated mice, respectively) deficits scores. In these mice the ischemic volume was also significantly reduced ($22.86 \pm 5.82 \text{ mm}^3$, $23.04 \pm 4.34 \text{ mm}^3$ respectively) compared to saline treated mice ($63.12 \pm 7.69 \text{ mm}^3$). This study shows that: i) DX-88, in its active form, can cross rapidly the intact blood-brain barrier and thus reach brain tissue; ii)
25 DX-88 has a significant neuroprotective effect against adverse consequences of brain ischemia and reperfusion injury.

Example 2: Neuroprotective effect of kallikrein inhibitor polypeptide administered at different times during brain ischemia and reperfusion injury

30 Ischemia was induced by occlusion of the middle cerebral artery by MCAO using a 6-0 monofilament. At the end of the 30 min ischemic period, the filament was removed and reperfusion allowed. Mice received DX-88 iv at the beginning of the ischemic period or at the end of it, during reperfusion.

It was first analyzed whether DX-88 was able to cross the blood-brain barrier and found that thirty minutes after treatment with 30µg/mouse iv, a marked inhibitory activity was present in CSF. The same dose of DX-88 was given at the beginning of ischemic period. Twenty four hours after ischemia, neurological deficits and infarct size were evaluated. While saline treated mice showed stable scores, those who received of DX-88 had significantly reduced general (by 37.5%) and focal (by 50.0%) deficits scores. In these mice the ischemic volume was also significantly reduced by 50.9%. When given at reperfusion, DX-88 was similarly effective in improving general (by 38%) and focal (by 50.1%) deficits scores as well as the ischemic volume that was reduced by 58%.

This study shows that: i) this specific kallikrein inhibitor can cross rapidly the intact blood-brain barrier and thus possibly reach brain tissue in its active form; ii) it has a significant neuroprotective effect against adverse consequences of brain ischemia and reperfusion injury.

A number of embodiments of the invention have been described. Nevertheless, it will be understood that various modifications may be made without departing from the spirit and scope of the invention. Accordingly, other embodiments are within the scope of the following claims.

The term “comprise” and variants of the term such as “comprises” or “comprising” are used herein to denote the inclusion of a stated integer or stated integers but not to exclude any other integer or any other integers, unless in the context or usage an exclusive interpretation of the term is required.

Any reference to publications cited in this specification is not an admission that the disclosures constitute common general knowledge in Australia.

The claims defining the invention are as follows:

1. A method for preventing or reducing blood loss in a patient, comprising administering to the patient a non-naturally occurring kallikrein inhibitor polypeptide in combination with an anti-thrombolytic agent.
2. The method of claim 1, wherein the blood loss is perioperative blood loss due to a surgical procedure performed on the patient.
3. The method of claim 2, wherein the surgical procedure is a cardiothoracic surgery.
4. The method of claim 3, wherein the cardiothoracic surgery is cardiopulmonary bypass or coronary artery bypass grafting.
5. The method of any one of claims 1 to 4, wherein the polypeptide comprises the amino acid sequence: Xaa1 Xaa2 Xaa3 Xaa4 Cys Xaa6 Xaa7 Xaa8 Xaa9 Xaa10 Xaa11 Gly Xaa13 Cys Xaa15 Xaa16 Xaa17 Xaa18 Xaa19 Xaa20 Xaa21 Xaa22 Xaa23 Xaa24 Xaa25 Xaa26 Xaa27 Xaa28 Xaa29 Cys Xaa31 Xaa32 Phe Xaa34 Xaa35 Gly Gly Cys Xaa39 Xaa40 Xaa41 Xaa42 Xaa43 Xaa44 Xaa45 Xaa46 Xaa47 Xaa48 Xaa49 Xaa50 Cys Xaa52 Xaa53 Xaa54 Cys Xaa56 Xaa57 Xaa58 (SEQ ID NO:1),

wherein Xaa1, Xaa2, Xaa3, Xaa4, Xaa56, Xaa57 or Xaa58 are each individually an amino acid or absent;

Xaa10 is an amino acid selected from the group consisting of: Asp and Glu;

Xaa11 is an amino acid selected from the group consisting of: Asp, Gly, Ser, Val, Asn, Ile, Ala and Thr;

Xaa13 is an amino acid selected from the group consisting of: Arg, His, Pro, Asn, Ser, Thr, Ala, Gly, Lys and Gln;

Xaa15 is an amino acid selected from the group consisting of: Arg, Lys, Ala, Ser, Gly, Met, Asn and Gln;

Xaa16 is an amino acid selected from the group consisting of: Ala, Gly, Ser, Asp and Asn;

Xaa17 is an amino acid selected from the group consisting of: Ala, Asn, Ser, Ile, Gly, Val,

Gln and Thr;

Xaa18 is an amino acid selected from the group consisting of: His, Leu, Gln and Ala;

Xaa19 is an amino acid selected from the group consisting of: Pro, Gln, Leu, Asn and Ile;

Xaa21 is an amino acid selected from the group consisting of: Trp, Phe, Tyr, His and Ile;

Xaa22 is an amino acid selected from the group consisting of: Tyr and Phe;

Xaa23 is an amino acid selected from the group consisting of: Tyr and Phe;

Xaa31 is an amino acid selected from the group consisting of: Glu, Asp, Gln, Asn, Ser, Ala, Val, Leu, Ile and Thr;

Xaa32 is an amino acid selected from the group consisting of: Glu, Gln, Asp, Asn, Pro, Thr, Leu, Ser, Ala, Gly and Val;

Xaa34 is an amino acid selected from the group consisting of: Thr, Ile, Ser, Val, Ala, Asn, Gly and Leu;

Xaa35 is an amino acid selected from the group consisting of: Tyr, Trp and Phe;

Xaa39 is an amino acid selected from the group consisting of: Glu, Gly, Ala, Ser and Asp;

Xaa40 is an amino acid selected from the group consisting of: Gly and Ala;

Xaa43 is an amino acid selected from the group consisting of: Asn and Gly;

Xaa45 is an amino acid selected from the group consisting of: Phe and Tyr; and wherein the polypeptide inhibits kallikrein.

6. The method of claim 5, wherein Xaa10 is Asp.
7. The method of claim 5 or claim 6, wherein Xaa11 is Asp.
8. The method of any one of claims 5 to 7, wherein Xaa13 is Pro, Xaa15 is Arg, Xaa16 is Ala, Xaa17 is Ala, Xaa18 is His and Xaa19 is Pro.
9. The method of any one of claims 5 to 8, wherein Xaa21 is Trp.
10. The method of any one of claims 5 to 9, wherein Xaa31 is Glu.

11. The method of any one of claims 5 to 10, wherein Xaa32 is Glu.
12. The method of any one of claims 5 to 11, wherein Xaa34 is Ile.
13. The method of any one of claims 5 to 12, wherein Xaa35 is Tyr.
14. The method of any one of claims 5 to 13, wherein Xaa39 is Glu.
15. The method of claim 5, wherein the polypeptide comprises: Met His Ser Phe Cys Ala Phe Lys Ala Asp Asp Gly Pro Cys Arg Ala Ala His Pro Arg Trp Phe Phe Asn He Phe Thr Arg Gln Cys Glu Glu Phe Ile Tyr Gly Gly Cys Glu Gly Asn Gln Asn Arg Phe Glu Ser Leu Glu Glu Cys Lys Lys Met Cys Thr Arg Asp, which is residues 3-60 of SEQ ID NO:2.
16. The method of claim 15, wherein the polypeptide further comprises a Glu-Ala sequence prior to the Met residue.
17. The method of any one of claims 1 to 16, wherein the anti-thrombolytic agent is an anti-fibrinolytic agent.
18. The method of claim 17, wherein the anti-fibrinolytic agent is selected from the group consisting of: tranexamic acid, epsilon amino caproic acid, aprotinin, Desmopressin (DDAVP), pirfenidone, and combinations thereof.
19. The method of claim 17, wherein the anti-fibrinolytic agent is epsilon amino caproic acid.
20. The method of claim 17, wherein the anti-fibrinolytic agent is aprotinin.
21. A method for preventing or reducing the onset of systemic inflammatory response associated with a surgical procedure in a patient comprising administering to the patient a non-naturally occurring kallikrein inhibitor polypeptide and an anti-thrombolytic agent.
22. A method for preventing or reducing cerebral ischemia in a patient, comprising: administering to the patient a non-naturally occurring kallikrein inhibitor polypeptide in combination with an anti-thrombolytic agent.

23. The method of claim 22, wherein the cerebral ischemia is a stroke.
24. The method of claim 23, wherein the stroke is selected from the group consisting of an embolism associated stroke, a thrombus-associated stroke, a thromboembolic stroke and a hemorrhage-associated stroke.
25. A method for preventing or reducing reperfusion injury in a patient, the method comprising administering to the patient a non-naturally occurring kallikrein inhibitor polypeptide in combination with an anti-thrombolytic agent.
26. The method of claim 25, wherein the reperfusion injury is reperfusion injury associated with cerebral ischemia.
27. The method of claim 26, wherein the cerebral ischemia is a stroke.
28. The method of claim 27, wherein the stroke is selected from the group consisting of an embolism associated stroke, a thrombus-associated stroke, a thromboembolic stroke and a hemorrhage-associated stroke.
29. The method of claim 7, wherein the polypeptide consists of residues 1-60 of SEQ ID NO:2.
30. The method of any one of claims 21 to 28, wherein the non-naturally occurring kallikrein inhibitor polypeptide comprises residues 3-60 of SEQ ID NO:2.
31. The method of any one of claims 21 to 28, wherein the non-naturally occurring kallikrein inhibitor polypeptide comprises residues 1-60 of SEQ ID NO:2.
32. The method of any one of claims 21 to 28, wherein the non-naturally occurring kallikrein inhibitor polypeptide consists of residues 3-60 of SEQ ID NO:2.

Dated: 21 April 2011

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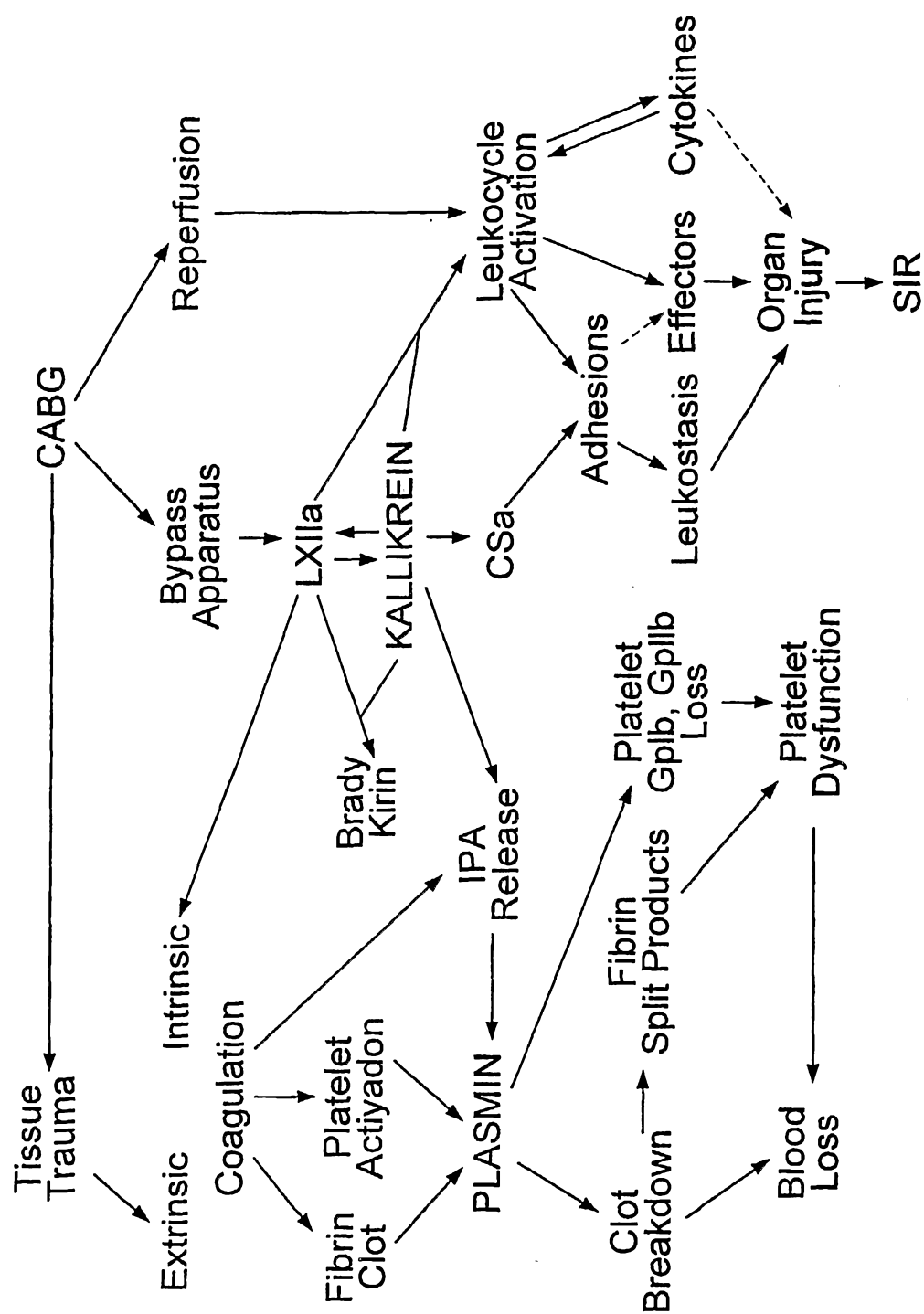


FIG. 1

5A0X1

BstB I

CG ACT TTT AAC GAC AAC TTG AGA AGA TCA AAA AAC AAC TAA TTA TTC GAA

ACG ATG AGA TTT CCA TCT ATC TTC ACT GCT GTT TTG TTC GCT GCT
M R F P S I F T A V L F A A

TCC TCT GCT TTG GCT GCT CCA GTT AAC ACC ACT ACT GAA GAC GAG ACT
S S A L A A P V N T T T E D E T

GCT CAA ATT CCT GCT GAG GCT GTC ATC GGT TAC TCT GAC TTG GAA GGT
A Q I P A E A V I G Y S D L E G

GAC TTC GAC GTC GCT GTT TTG CCA TTC TCT AAC TCT ACT AAC AAC GGT
D F D V A V L P I S N S T N N G

TTG TTG TTC ATC AAC ACT ACC ATC GCT TCT ATC GCT GCT AAG GAG GAA
L L F I N T T I A S I A A K E E

GGT GTT TCC CTC GAG AAG AGA GAG GCT ATG CAC TCT TTC TGT GCT TTC
G V S L E K R E A M H S F C A F

AAG GCT GAC GAC GGT CCG TGC AGA GCT GCT CAC CCA AGA TGG TTC TTC
K A D D G P C R A A H P R W F F

AAC ATC TTC ACG CGT CAA TGC GAG GAG TTC ATC TAC GGT GGT TGT GAG
N I F T R Q C E E F I Y G G C E

GGT AAC CAA AAC AGA TTC GAG TCT CTA GAG GAG TGT AAG AAG ATG TGT
G N D N R F E S L E E C K K M C

EcoR I

ACT AGA GAC TAG TAA GAA TTC GCC TTA GAC ATG ACT GTT CCT CAG TTC
T R D * *

3' AOX1

AAG TTG GGC ACT TAC GAG AAG
3' AOX1

FIG. 2

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SEQ ID 2:(amino acids 3 60) -- MHSFCAFKA-DDGPCRAAHPRNIFNFTROCEEFITYGG
SEQ ID 4: ---MHSFCAFKA-DDGPCKANHLRFFFNIFTROCEEFITYGG
SEQ ID 5: ----MHSFCAFKA-DDGHCKANHQRFFFNIFTROCEEFITYGG
SEQ ID 6: -- -MHSFCAFKA-DDGHCKANHQRFFFNIFTROCEEFITYGG
SEQ ID 7: ----MHSFCAFKA-DDGHCKASLPRFFFNIFTROCEEFITYGG
SEQ ID 8: ---MHSFCAFKA-DDGHCKANHQRFFFNIFTROCEEFITYGG
SEQ ID 9: - MHSFCALKA-DDGHCKGAHLRFFFNIFTROCEEFITYGG
SEQ ID 10: - -MHSFCAFKA-DDGRCKGAHLRFFFNIFTROCEEFITYGG
SEQ ID 11: - MHSFCALKA-DDGRCKGAHPRWFFNIFTROCEEFITYGG
SEQ ID 12: ----MHSFCAFKA-DDGPCRAAHPRWFFNIFTROCEEFITYGG
SEQ ID 13: ----MHSFCAFKA-DVGRCKGAHPRWFFNIFTROCEEFITYGG
SEQ ID 14: ----MHSFCAFKA-DVGRCKGAQPRFFFNIFTROCEEFITYGG
SEQ ID 15: ---MHSFCAFKA-DDGSCRAAHLRWFFNIFTROCEEFITYGG
SEQ ID 16: ----MHSFCAFKA-EGGSCRAAHQRWFFNIFTROCEEFITYGG
SEQ ID 17: ----MHSFCAFKA-DDGPCRGAHLRFFFNIFTROCEEFITYGG
SEQ ID 18: ---MHSFCAFKA-DDGHCKGALPRWFFNIFTROCEEFITYGG
SEQ ID 19: ----MHSFCAFKA-DSGNCRGNLPRFFFNIFTROCEEFITYGG
SEQ ID 20: ----MHSFCAFKA-DSGRCKGNHQRFFFNIFTROCEEFITYGG
SEQ ID 21: -- -MHSFCALKA-DDGRCKRAIQPRWFFNIFTROCEEFITYGG
SEQ ID 22: ----MHSFCAFKA-DDGRCKGAHPRWFFNIFTROCEEFITYGG
BP11(SEQ ID 29): ----RPDFCILEPP-YTGPCKARIIRYFYNAKAGLCQTFVYGG
ITI-D1(SEQ ID 30): ---KEDSCQLGY-SAGPCMGMTSRYFYNGTSMACQTFVYGG
ITI-D2(SEQ ID 31): ----TVAAACNLPI-VRGPCRAFIQLWAFDAVKGKCVLFPYGG
LACI-D1(SEQ ID 32): ----MHSFCAFKA-DDGPCKAIMKRFFFNIFTROCEEFITYGG
LACI-D2(SEQ ID 33): ----KPDFCFLEE-DPGICRGYITRYFYNNQTKQCFERFVYGG
LACI-D3(SEQ ID 34): ----GPSWCLTPA-DRGLCRANENRFYNSVIGKCRPFKYSG
HKI B9(SEQ ID 35): - -LPNVCAIPM-EKGPCQTYMTRWFFNFETGECELFAYGG
C-3(SEQ ID 36): ----ETDICKLPK-DEGTCRDFILKWYYDPNTKSCARFVYGG
TFPI-2 D1(SEQ ID 37): ----NAEICLLPL-DYGPCRAALLRYYYDRYTQSCRQFLYGG
TFPI-2 D2(SEQ ID 38): -- -VPKVCRLQVSVDQCEGSTEKYFFNLSSMTCEKFFSSG
TFPI-2 D3(SEQ ID 39): ----IPSFICYSPK-DEGLCSANVTRYFYFNPRYRTCDAFITYG
APP-I(SEQ ID 40): - -RNREVCSEQA-ETGPCRAMISRWFVDVTEGKCAPFFYGG
EpiNE7(SEQ ID 41): ----RPDFCILEPP-YTGPCVAMFPRYFYNAKAGLCQTFVYGG
BITI E7-141(SEQ ID 42): --RPDFCQLGY-SAGPCVAMFPRYFYNGTSMACQTFVYGG
MUTT26A(SEQ ID 43): ----RPDFCQLGY-SAGPCVAMFPRYFYNGASMACQTFVYGG
MUTQE(SEQ ID 44): ----RPDFCQLGY-SAGPCVAMFPRYFYNGTSMACQTFVYGG
MUT1619(SEQ ID 45): ----RPDFCQLGY-SAGPCVGMFSRYFYNGTSMACQTFVYGG
EPI-HNE 1(SEQ ID 46): EAEARPDFCILEPP-YTGPCIAFFPRYFYNAKAGLCQTFVYGG
EPI-HNE-2(SEQ ID 47): -----AACNLPI-VRGPCIAFFPRWAFDAVKGKCVLFPYGG
EPI-HNE 3(SEQ ID 48): -----AACNLPI-VRGPCIAFFPRWAFDAVKGKCVLFPYGG
EPI-HNE-4(SEQ ID 49): -----EACNLPI-VRGPCIAFFPRWAFDAVKGKCVLFPYGG
DPI14 KR(SEQ ID 50): - -EAVREVCSEQA-ETGPCIAFFPRWYFDVTEGKCAPFFYGG
DPI24 KR(SEQ ID 51): --EANAEICLLPL-DYGPCIAFFPRYYYDRYTQSCRQFLYGG
DPI68 KR(SEQ ID 52): --EAKPDFCFLEE-DPGICIGFFPRYFYNNQAKQCFERFVYGG
DPI84 KR(SEQ ID 53): - -EAETDICKLPK-DEGTCIAFFPRWYYPNTKSCARFVYGG

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FIG. 3A
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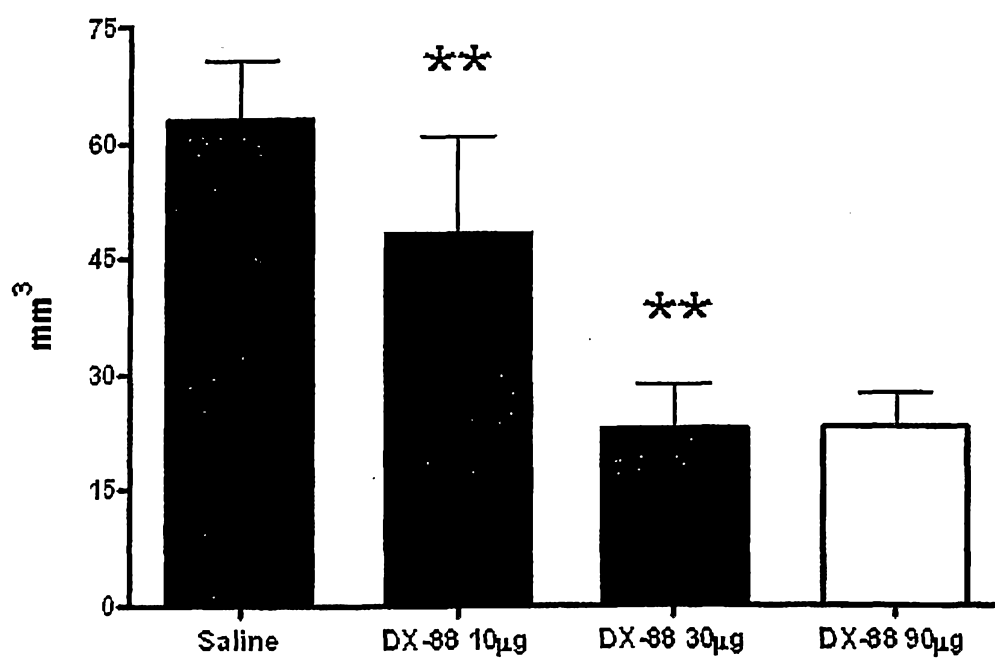
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SEQ ID 4: (cont.)	CGGNQ--NRFESLEECKKMCTRD
SEQ ID 5: (cont.)	CGGNQ--NRFESLEECKKMCTRD
SEQ ID 6: (cont.)	CAGNQ--NRFESLEECKKMCTRD
SEQ ID 7: (cont.)	CGGNQ--NRFESLEECKKMCTRD
SEQ ID 8: (cont.)	CGGNQ--NRFESLEECKKMCTRD
SEQ ID 9: (cont.)	CEGNQ--NRFESLEECKKMCTRD
SEQ ID 10: (cont.)	CEGNQ--NRFESLEECKKMCTRD
SEQ ID 11: (cont.)	CGGNQ--NRFESLEECKKMCTRD
SEQ ID 12: (cont.)	CGGNQ--NRFESLEECKKMCTRD
SEQ ID 13: (cont.)	CGGNQ--NRFESLEECKKMCTRD
SEQ ID 14: (cont.)	CGGNQ--NRFESLEECKKMCTRD
SEQ ID 15: (cont.)	CGGNQ--NRFESLEECKKMCTRD
SEQ ID 16: (cont.)	CGGNQ--NRFESLEECKKMCTRD
SEQ ID 17: (cont.)	CGGNQ--NRFESLEECKKMCTRD
SEQ ID 18: (cont.)	CGGNQ--NRFESLEECKKMCTRD
SEQ ID 19: (cont.)	CGGNQ--NRFESLEECKKMCTRD
SEQ ID 20: (cont.)	CGGNQ--NRFESLEECKKMCTRD
SEQ ID 21: (cont.)	CGGNQ--NRFESLEECKKMCTRD
SEQ ID 22: (cont.)	CGGNQ--NRFESLEECKKMCTRD
BP11(SEQ ID 29): (cont.)	CRAGR--NNKSAEDCMRICGGA
ITI-D1(SEQ ID 30): (cont.)	CMGNG--NNFVTEKECLQTCRTV
ITI-D2(SEQ ID 31): (cont.)	CGNG--NKFYSEKECREYCGVP
LACI-D1(SEQ ID 32): (cont.)	CEGNQ--NRFESLEECKKMCTRD
LACI-D2(SEQ ID 33): (cont.)	CLGNM--NNFETLEECKNICEDG
LACI-D3(SEQ ID 34): (cont.)	CGGNE--NNFTSKQECLRACKKG
HKI B9(SEQ ID 35): (cont.)	CGGNS--NNFLRKEKCEKFKIT
C-3(SEQ ID 36): (cont.)	CGGNE--NKFQSQKECEKVCAPV
TFPI-2 D1(SEQ ID 37): (cont.)	CEGNA--NNFYIWEACDDACWRI
TFPI-2 D2(SEQ ID 38): (cont.)	CHRNRIENRFPDEATCMGFCAPK
TFPI-2 D3(SEQ ID 39): (cont.)	CGGND--NNFVSREDCKRACAKA
APP-I(SEQ ID 40): (cont.)	CGGNR--NNFDTEEYCMAVCGSA
EpiNE7(SEQ ID 41): (cont.)	CMGNG--NNFKSAEDCMRTCGGA
BITI E7-141(SEQ ID 42): (cont.)	CMGNG--NNFVTEKDCLQTCRGA
MUTT26A(SEQ ID 43): (cont.)	CMGNG--NNFVTEKDCLQTCRGA
MUTQE(SEQ ID 44): (cont.)	CMGNG--NNFVTEKDCLQTCRGA
MUT1619(SEQ ID 45): (cont.)	CMGNG--NNFVTEKDCLQTCRGA
EPI-HNE 1(SEQ ID 46): (cont.)	CMGNG--NNFKSAEDCMRTCGGA
EPI-HNE 2(SEQ ID 47): (cont.)	CGNG--NKFYSEKECREYCGVP
EPI-HNE 3(SEQ ID 48): (cont.)	CGNG--NKFYSEKECREYCGVP
EPI-HNE 4(SEQ ID 49): (cont.)	CGNG--NKFYSEKECREYCGVP
DPI14 KR(SEQ ID 50): (cont.)	CGGNR--NNFDTEEYCMAVCGSA
DPI24 KR(SEQ ID 51): (cont.)	CEGNA--NNFYIWEACDDACWRI
DPI68 KR(SEQ ID 52): (cont.)	CLGNM--NNFETLEECKNICEDG
DPI84 KR(SEQ ID 53): (cont.)	CGGNE--NKFQSQKECEKVCAPV

FIG. 3B
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Ischemic volume

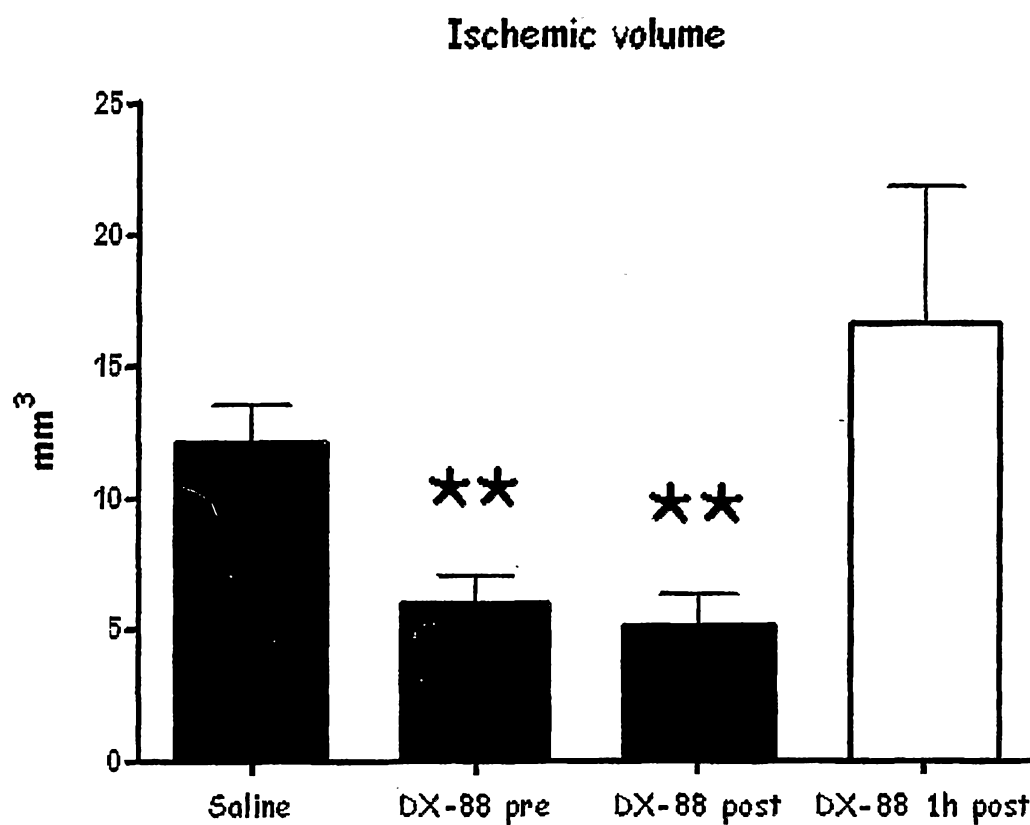
Ischemic volume
(dose-response)



Data are expressed as mean and SEM (n=6-8)

FIG. 4

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Data are expressed as mean and SEM (n=6-8)

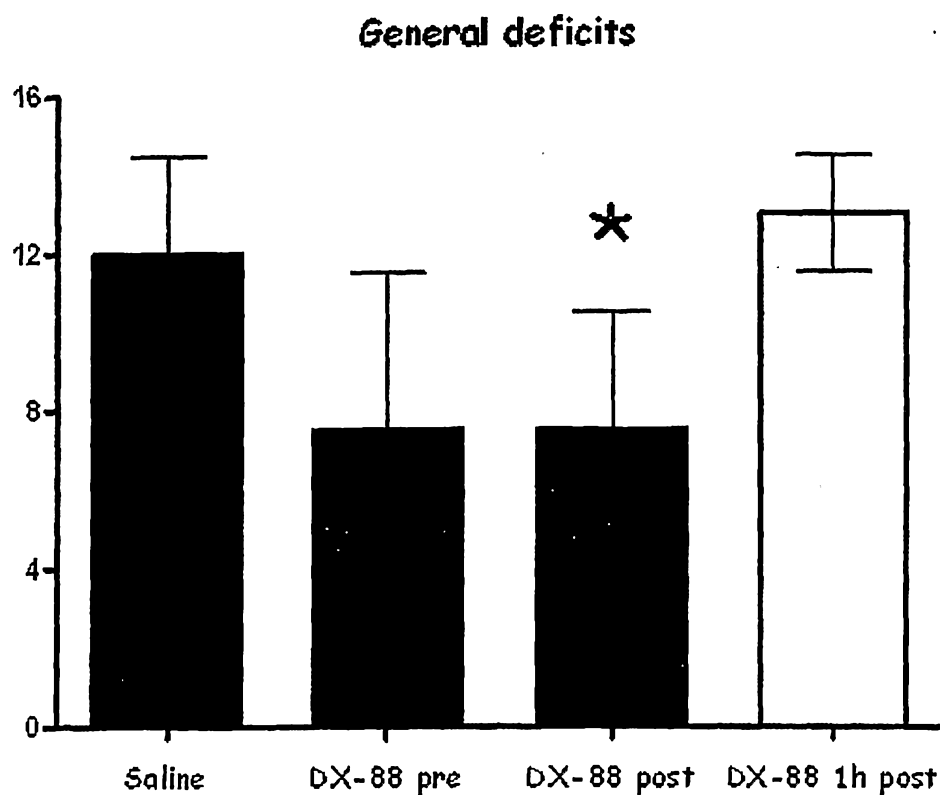
FIG. 5

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General Neurological Deficits

Hair 0 - 2
Ears 0 - 2
Eyes 0 - 4
Posture 0 - 4
Spontaneous activity 0 - 4
Epileptic behaviour 0 - 12

TOTAL 0 - 28



Data are expressed as median and interquartile (n=6-8)

FIG. 6

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Focal Neurological Deficits

Body symmetry	0 - 4
Gait	0 - 4
Climbing	0 - 4
Circling behaviour	0 - 4
Front limb symmetry	0 - 4
Compulsory circling	0 - 4
Whisker response	0 - 4
<hr/>	
TOTAL	0 - 28

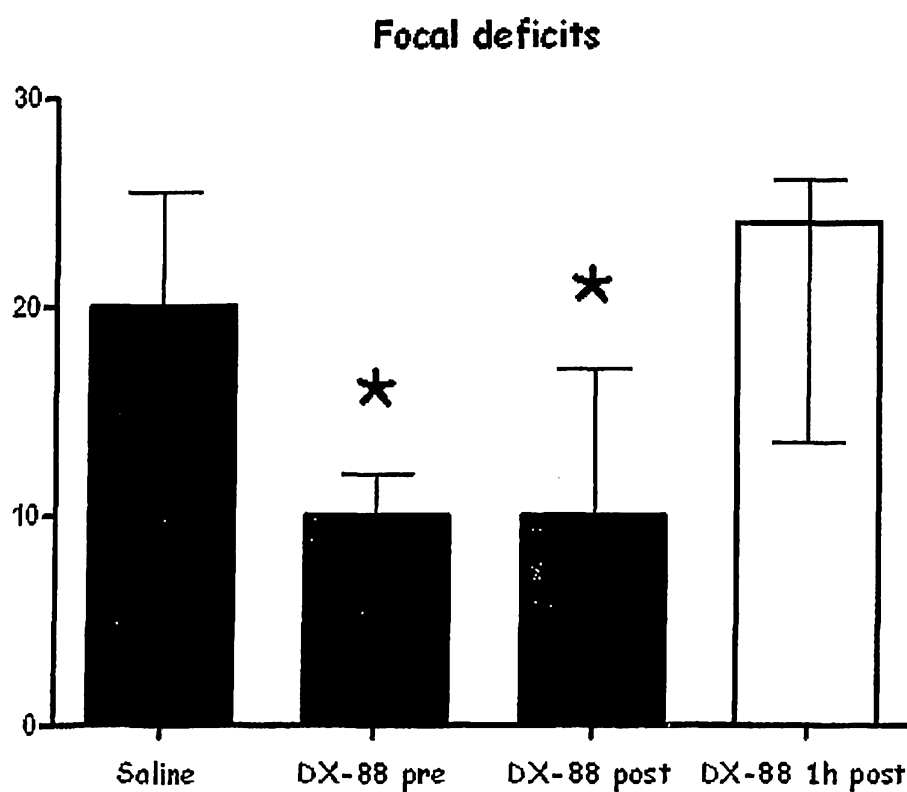


FIG. 7
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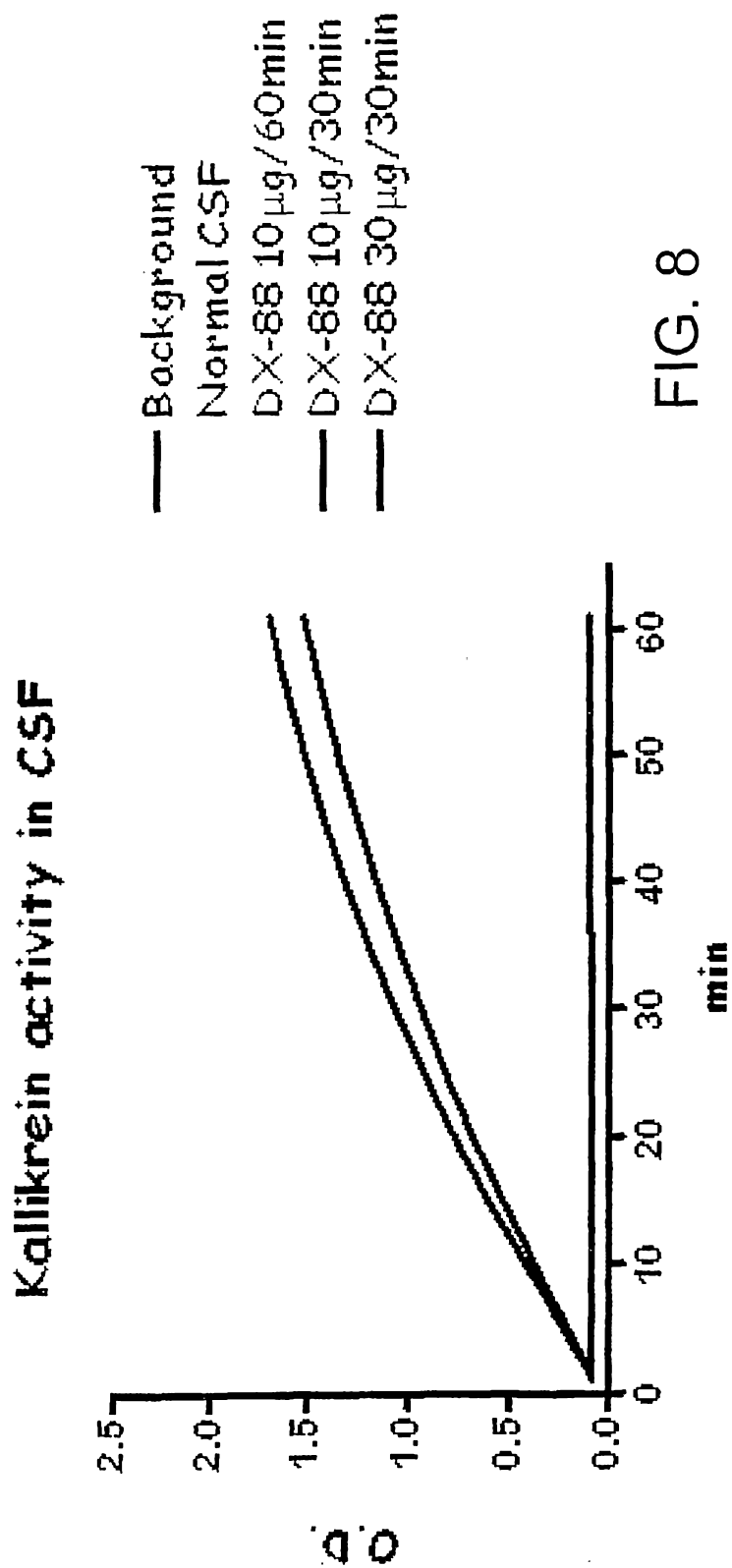


FIG. 8